Electrochemical Industry

VOL. I. PHILADELPHIA, NOVEMBER 1, 1902. NO. 3.

Electrochemical Industry

Published on the first of each month by the

ELECTROCHEMICAL PUBLISHING COMPANY,

[*Incorporated.*]

CITY TRUST BUILDING, PHILADELPHIA, PA.

J. W. RICHARDS, PH.D.....*President.*

E. F. ROEBER, PH.D.....*Editor.*

HERBERT W. POOL.....*Advertising Manager.*

Long Distance Telephone 3-51-24.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies, 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Copyrighted, 1902, by the Electrochemical Publishing Co.

Application made for Entry as Second-Class Matter at the Philadelphia Post-Office.

CONTENTS.

Editorial 81
The Opening of the Water Works and Power Plant at Sault Ste. Marie 84
Electrochemical Units. By A. H. Cowles..... 84
Developments in Electrometallurgy of Iron and Steel. By Marcus Ruthenborg 84
Electrochemistry at Sault Ste. Marie. By Joseph W. Richards.... 85
The Thallium Storage Cell. By A. L. Marsh..... 88
Annual Meeting American Electrochemical Society..... 89
Pioneers of Electrochemistry—III. E. G. Acheson..... 90
Low Temperature Researches. By James Dewar..... 91
Professor Rowland's Works..... 96
Obituary: G. H. Gladstone..... 96
Analysis of Current Electrochemical Patents. By George P. Scholl 97
Electrochemistry at the World's Fair, St. Louis. By W. E. Goldsborough 101
Electrochemical Theories Illustrated by Examples from Practice: Faraday's Law and the Theory of Electrons..... 102
Current Notes..... 103
Synopsis of Articles in Other Journals. By Carl Hering..... 104
Some European Power Plants. By Frank C. Perkins..... 109
Correspondence: Mr. Cowles' Pioneer Work. By F. C. McMillin 110
Book Reviews..... 111
Books Received..... 112
Electric Laboratory Furnaces..... 112
Voltmeter for Electroplating Plants..... 113
Personal 113
Industrial Notes..... 113
Digest of U. S. Patents Prior to July, 1902. (Diaphragm Cells for the Production of Caustice Alkali.) By Byrnes & Townsend 114

SAULT STE. MARIE.

The opening of the hydro-electric plant of the Michigan Lake Superior Co., at Sault Ste. Marie, which is exceeded in size only by that at Niagara Falls, marks a new epoch in the development of this young industrial center. Under the energetic management of the Clergue Syndicate, the development of the Canadian "Soo" has been rapid in recent years. Now, after the opening of the Michigan power house, the development of the American side promises to be not less impressive. Nor should there be any doubt that the development of the "Soo" in the future will be closely allied with the advance of electrochemical industries.

Perhaps the most important condition which determined the general engineering features of the new power plant was the low available head of only 20 feet. It necessitated the installation of a great many generating units of comparatively small size. The total capacity of the power house is 32,000 kilowatts, in 80 units of 400 kilowatts each. This large number of small units accounts for the enormous size of the plant.

We publish in this issue an interesting article by Dr. J. W. Richards, on the present industrial conditions of the "Soo" and on the outlook for the future, especially with respect to electrochemical industries. The main reason why one may safely prophesy that the development of the "Soo" will be closely allied with electrochemical enterprise is the fact that the distance of Sault Ste. Marie from any large city is too great to justify transmission of power. The power generated there is to be consumed at the spot. The location is very favorable for cheap transportation of the goods, either by water or on railways. The conditions are therefore fulfilled which should enable the "Soo" to become an important industrial center, like Niagara Falls. In fact, the marvelous development of the "Soo" in the last few years leaves no doubt concerning the future. Electrochemical industries have already participated in this development. There is the alkali plant, using the Rhodin process, which, however, is not in operation at present. For the manufacture of calcium carbide, a large amount of the power of the new power house has already been contracted for. And last, but not least, there are very promising prospects for developments in the electrometallurgical line, especially for the treatment of Lake Superior copper and Sudbury nickel.

It is perhaps superfluous to remark that electrochemical plants, with their uniform continuous load and their very high load factor, are the ideal customers for a great power plant, and that therefore the managers of power plants are fully justified in making special inducements to electrochemical enterprise. We wish great success to the energetic managers of the enterprise at Sault Ste. Marie, and we trust that in future we may often have to record advances of electrochemistry and electrometallurgy at the "Soo."

LOW TEMPERATURE RESEARCHES.

We need offer no apology for devoting much space this month to the publication, nearly in full, of Prof. James Dewar's presidential address to the British Association on this subject, which, although not directly electrochemical, is of the highest interest, as it refers to a field on which very little is yet known and which may become of great importance in the future. Professor Dewar's extended researches in this field render his address an authoritative statement of our present knowledge in this line.

Electrochemical processes, as far as they are not performed at ordinary temperatures, have up to the present been essentially high-temperature processes. The electrical furnace is the ideal means of producing high temperatures, which are, indeed, limited only by the difficulty of finding sufficiently refractory materials for the furnace walls. Electric furnace researches have given us a new chemistry—that of high temperatures—and these researches have already brought many fruitful industrial results. There is great difficulty in these researches, in so far as it seems impossible at present to predict what one will get in such a process. In fact, a very prominent investigator and pioneer in this line once stated in a private conversation that it is impossible to work according to a clearly predetermined plan; the only way is to put materials into the furnace, turn on the current and wait to see what one will get. This may seem a rough and unscientific way, but it nevertheless states correctly the limits of our present knowledge.

There is, indeed, a remarkable difference between the chemistry at high and at low temperatures. Prof. J. H. van't Hoff has emphasized this difference in one of his lectures on physical chemistry, held at the celebration of the tenth anniversary of the University of Chicago last year, while discussing Berthelot's "principe du travail maximum." This principle is very simple. It states that the amount of heat which a chemical action evolves indicates at the same time in which direction the reaction will occur. If there is a possibility of the evolution of heat by means of a chemical reaction, this reaction, and not the reverse, will take place. Indeed, this principle is correct in a great many instances, and is a very useful means to predict, under normal conditions, what will happen. But there are cases where the actual facts clearly contradict this law. Professor van't Hoff points out that when one considers this matter from the point of view of the second principle of thermodynamics, then Berthelot's principle appears to be correct at temperatures near the absolute zero point. That Berthelot's principle is found to agree with so many observations in ordinary chemistry is simply a result of the fact that at the ordinary temperature of chemical experiments we are relatively near the absolute zero of temperature. At 1,000° Celsius the processes occur in a quite different manner, and often in a way which is opposite to Berthelot's principle. The lower the temperature the better we are able to predict things by means of Berthelot's principle. Whether the low-temperature researches will have important industrial results can only be borne out by the development of the future, but it must be said that it is quite likely that this will be the case

FARADAY'S LAW AND THE THEORY OF ELECTRONS.

In this issue we publish an article on this subject which we believe may be of interest to the practical electrochemical engineer. The modern hypothesis of electrons is usually regarded to be of theoretical value only, and practical men are somewhat inclined to scorn it. In the article to which we refer an attempt is made to show that this hypothesis ought to be useful to the practical man, as it offers a very simple and safe means of applying Faraday's law, which should certainly not be despised, as it is surprising to see how often mistakes are made in numerical applications of this fundamental law of electrolytic action.

Most electrochemical text-books state Faraday's law either in too vague or too narrow a sense. We say "too vague," as very often this law is given more qualitatively than quantitively. But what the engineer needs is an exact, concise method by which he can calculate numerically in any case the theoretical output in pounds or kilograms per ampère hour. The law is also given in too narrow a sense, by stating merely the relation between the ampère hours and the weight of ions "liberated at the electrodes." One, then, cannot apply it to cases in which no ions are liberated, but where there is a simple change of valence, as at the carbon electrode in the Bunsen cell or in the chromium cell. It is indeed difficult to give briefly a complete and concise statement of Faraday's law, and it is much easier to form a mechanical model or image suitable for all cases and based upon the hypothesis of ions and electrons. Of course, if such a hypothesis is useful for such purposes, this should not be taken as a proof of the complete correctness of the hypothesis, and one should bear in mind that the use of such mechanical models is comparable to using crutches in walking. But it is certainly better to reach a goal safely by means of crutches than not to reach it at all.

It is interesting to note how closely Professor Johnson's notation of "bonds," which was based purely on chemical considerations, applies to electrochemical problems if only positive and negative bonds are considered as positive and negative electrons. This is an example showing that in natural science there are many ways by which one may approach a certain goal, but the final result must always be the same if it is to represent the truth. Yet the same truth may be expressed in different ways or by different images, according to the point of view from which one looks at it.

STORAGE BATTERY INVENTION.

In this issue we publish an article by Prof. A. L. Marsh, on the thallium storage cell, which is quite interesting in several respects from a scientific point of view, although, as the author states, it is unsuitable for the purposes of the practice. The principal reason why this cell must fail in practice is that the electrodes are not insoluble in all states of charge and discharge. From the experience of a great number of inventors, who for a long series of years have made extended experiments and trials with new storage batteries, it seems safe to conclude that the solubility of an electrode in any state of charge or discharge is fatal to the commercial success of the

battery. It is worth while to discuss this point somewhat in detail.

There are two reasons which may cause the failure of a battery due to solubility of an electrode. The first refers only to batteries with electrodes of two metals. For instance, should in a zinc-copper cell with an alkaline electrolyte copper go into solution, the copper ions will go to the zinc electrode during charge, and will be deposited on the zinc; this copper deposited on the zinc will form, together with the zinc, a short-circuited couple, and zinc will be dissolved, the total chemical energy lost being changed into Joulean heat. In its result this is equivalent with local action. In the same battery zinc goes into solution, but it is not deposited on the copper; hence there is here not the same disadvantage inherent in the solubility of the zinc as in the solubility of the copper. From this the rule results which has been recognized as correct for years—that in a storage battery with electrodes of two different metals the electrode, which is the cathode during discharge (or the anode during charge), should be insoluble in any state of charge or discharge. Of course, this rule has no effect on the thallium cell, because thallium is the only metal used in this cell.

The second reason why no soluble electrodes should be used is of universal importance, and is pointed out clearly by Professor Marsh when he speaks of the difficulties of obtaining compact, evenly-distributed and adherent deposits. The experience of electroplaters proves that to get good adherent deposits of any metal special conditions must be carefully observed. It is evident that this is strictly impossible in storage-battery practice. Hence during charge there will always occur deposits in spongy or not adherent form, and this will result in short circuits. This has been proven conclusively by the trials which have been made with the zinc-lead peroxide accumulator, which has otherwise distinct advantages over the ordinary lead cell.

The rule that a storage cell should not contain any soluble electrode is fulfilled in the lead cell, and is claimed to be fulfilled in the Edison iron-nickel accumulator, which may be considered at present as the most promising rival of the lead cell. Edison's iron-nickel cell has just this advantage of the unsolubility of the electrodes over the old Edison-Lalande cell. While the thallium cell—or the general type of which it is a special case—has certainly distinct interesting features, which are clearly brought out by Professor Marsh, there cannot be any doubt that neither this cell nor any other cell of the same type is applicable for commercial work.

CAUSTIC SODA BY THE DIAPHRAGM PROCESS.

In the first two issues of this journal we published, in the Digest of United States Patents, prepared by Messrs. E. A. Byrnes and C. P. Townsend, a complete review of the patents referring to the electrolysis of sodium chloride with mercury cathodes. We commented editorially in our last issue upon an important point in connection with this class of processes. In our present issue we publish the first part of the review of the patents referring to diaphragm processes.

It is a chemical commonplace that the rate of chemical change is proportional to the active mass of the reacting substances, and that the only chemical changes which are truly complete are those in which one at least of the final products assumes a physical condition which withdraws it from the sphere of reaction. This mass law has its direct applications to electrolytic work, but, without following them too closely, it may be remarked that in general the electrolytic methods which work at high efficiency are those in which one at least of the products passes into an insoluble state, or is otherwise withdrawn from the field of electrolytic action. If the physical character of the resultant product, primary or secondary, is such as to insure its isolation, the efficiency will be high.

It so happens, however, that many of the most important industrial electrolytic products are soluble in their electrolytes, either directly or by reaction therewith, and it is around such that the most formidable difficulties cluster. Since they are not isolated by virtue of their physical state, it is essential that means be provided for shielding them from the influence of the current and of the electrolyte, and from this necessity has arisen the type of diaphragm cells.

Caustic soda occupies the peak of the trouble line. If the metal sodium be absorbed by a mercury cathode, and by it carried from the region of reaction, the field is left clear and the efficiency is high. If, however, it be permitted to oxydize at the cathode, the efficiency will depend directly upon the effectiveness of the means employed for the restriction of the caustic solution to this point. For this reason, and because, to an investigator, failure has much the same value as success, provided only the causes be recognized, there is no more suggestive field for study than the efforts, past and present, to compass the direct conversion of brine into caustic.

ELECTROCHEMICAL TERMINOLOGY.

The Standardization Committee of the American Institute of Electrical Engineers has done excellent work in standardizing methods of testing and paving the way towards the use of a uniform terminology in electrical engineering. We hope the American Electrochemical Society will undertake the same task for industrial and scientific electrochemistry, for it cannot be denied that at present a great confusion prevails in electrochemical terminology. We may only call attention to the different sense in which the terms positive and negative plate of an accumulator are used. In scientific electrochemistry a great deal of very valuable work has been done in Germany, but it must be said that the terminology introduced by the Germans is often misleading, and often, when the German terms are correct, the translation is wrong. For instance, Kohlrausch's "Beweglichkeit" of an ion is usually translated as ionic speed or velocity, which is simply wrong, because the dimensions are not those of a velocity. Finally, the notification in books on electrochemistry should be simplified; it should agree with that generally used by electrical engineers.

Electrochemical engineers and scientists should remember that they are workers in the same field, and the American Electrochemical Society should use their authority to bring about uniformity of terms and notation.

THE OPENING OF THE WATER WORKS POWER PLANT AT SAULT STE. MARIE, MICHIGAN.

At noon, October 25th, occurred the formal opening of the water-power plant of the Michigan Lake Superior Power Co. at Sault Ste. Marie, Mich. The event is an important one, not only to the citizens of that locality, but to the electrochemical industry in general, because it marks the beginning of operation of the second largest water-power electric plant in this country. All of the important features of the hydraulic installation at this place are described in the article by Dr. J. W. Richards on another page of this issue.

Mr. H. von Schon has been chief engineer of the undertaking. Mr. W. Owen Thomas is electrical engineer in charge of the electrical work, and designed many of the interesting electrical features.

At the present time the market for the company's electrical output is practically undeveloped at the Soo, and there is abundant power for industries desiring cheap electrical power. The investment in the completed plant will be, it is announced, about $4,000,000, or $135 per kilowatt. This is not high as investments in water plants run, and the company ought to be able to make a very low rate.

At the formal opening, on October 25th, shortly after noon, Chief Engineer von Schon spoke a few introductory words. Mr. F. H. Clergue, the head of the whole enterprise, answered briefly, and Miss Helen Clergue then stepped forward and, by closing the switch, set the machinery in motion.

A banquet on the evening of October 27th closed the festivities.

ELECTROCHEMICAL UNITS.

In our last issue (page 60) we published a longer abstract of Mr. Alfred H. Cowles' interesting American Electrochemical Society paper, in which he proposes a new system of electrochemical units, based upon the following very simple relation found by him: 100 ampères liberate one cubic meter of hydrogen in one day. We are indebted to Mr. Cowles for the following additional information:

Based upon this relation, he proposes that this quantity of electricity be called a kilocrith col, as the weight of a cubic meter of hydrogen is a kilocrith, or 1,000 criths. The calculation from which the foregoing agreement is found can be made from the following data: In the "Smithsonian Contributions to Knowledge" for 1896 is printed Dr. Edward W. Morley's classic paper on the atomic weights of oxygen and hydrogen. In the same he gives the weight of a crith, or one cubic decimeter of hydrogen, as .089873 = .0000027 grams at 0° C., 45° Lat, and at the mean atmospheric pressure at sea level. If the atomic weight of hydrogen be taken as one, we must then attribute an atomic weight of 107.11 to silver, and, taking Lord Rayleigh's determination of the electrochemical equivalent of silver, .001118 grams per coulomb, the electrochemical equivalent of hydrogen becomes .00001043786 grams. Under these premises, the kilocrith col, or 100 international ampères, for one siderial day liberate 1.00071 cubic meters of hydrogen under normal conditions. Of course, this can be reduced to a crith col by dividing in each case by 1,000, in which case we have the electric quantity that will free a crith or liter of hydrogen.

We may use this opportunity to correct a typographical error which occurred in our abstract in the last issue, where, in stating the above relation, one cc. was said, instead of one cubicmeter. The two remarkable relations found by Mr. Cowles are exactly stated, as follows: First, 500 ampères in one solar day decompose practically (within ½ per cent.) one pound (avoirdupois) molecule of any univalent compound; and, second, 100 ampères in one siderial day liberate one (exactly, 1.00071, from the best available figures) cubic meter of hydrogen under normal conditions.

DEVELOPMENTS IN ELECTROMETALLURGY OF IRON AND STEEL.

An interesting paper on this subject, which appears to become of commercial importance, was read at the Niagara meeting of the American Electrochemical Society, by Marcus Ruthenberg. It is well known that many iron ores occur throughout the world, which are too low in tenure to permit smelting. If the iron in these ores occurs as magnetite Fe_3O_4, it permits of a concentration by means of magnetic separators. Magnetites occur but seldom of such purity that they are entirely free from sulphur and phosphorus, and it depends very largely upon what portion of the ore these two metals are associated with, as to the fineness to which the ore must be ground, and its particular treatment in the magnetic machines. It is found that when ores are ground finely and an attempt is made to magnetically concentrate them dry, there is a measure of adhesion between the particles of magnetic and non-magnetic portions that will not permit of cleanly work; this is obviated by handling the ground ore in water, in which case the water seems to lubricate the particles so that the magnetic portions come away cleanly. A clean, fine, blue-black powder is thus obtained which may go anywhere from 65 to 72 per cent. of magnetic iron, pure peroxide being 72.40. It then becomes a question as to how this iron ore may be handled in a furnace. The author discusses critically several methods which can be used and have been suggested for this purpose. He then describes an entirely new method which he has had in use for upwards of a year.

This method consists in taking the concentrates cleaned up to the highest point of possible purity, and putting them through an electric furnace, the melting zone of which is a magnetic field. The ore being magnetic, and the polar projections of this magnetic field being at the same time the electrodes of the smelting circuit, the magnetic bridge thus formed by the ore forms a high resistance in the smelting circuit. The heat of the smelting circuit is engendered within this bridge of ore itself. The electrodes are water-cooled. The moment that the ore melts it loses its magnetism, and gathering weight from new molten material being added to it, it falls out of the magnetic field, its place being taken by fresh portions of ore from above. The result of this operation is agglomerated, coherent masses, ranging in size from a bean to a walnut, that are hard, strong, tough and porous, differing in analysis in no way from the ore prior to its agglomeration except for the absence of moisture and the last traces of sulphur. The product is in an ideal condition for use in the blast furnace.

If reducing material, such as powdered coke dust or charcoal dust be added to the charge prior to its introduction to the electric furnace, a partial reduction takes place and the fritted mass of carbonaceous dust and iron ore, partially reduced, is dropped into a soaking pit. If allowed to remain in this soaking pit a proper length of time, cementation takes place through the action of the heat left in the ore, by the electric furnace, and the action of the carbon fritted into the mass, which results in producing reduced metal, which may be properly termed steel. This material from the soaking pits is ideal for melting in the open-hearth furnace. It thus becomes possible to produce first-class steel direct from the ore, through the intermediation of the electric furnace and the soaking pit, producing spongy iron or steel ready for immediate melting in the open hearth, without the intervention of the blast furnace in any part.

The author believes that this process could be used to great advantage for many low-grade ores. He especially refers to ferruginous beach sands which occur in many parts of the world, notably on the St. Lawrence River and on the Pacific Coast.

For further details, the reader must be referred to the full paper, published in the "Transactions" of the Society, which will come out at the end of this month.

ELECTROCHEMISTRY AT SAULT SAINTE MARIE.

BY JOSEPH W. RICHARDS,
President of the American Electrochemical Society.

A DESCRIPTION kept conscientiously within the above title would be very brief. It would cover a description of the Rhodin process of manufacturing caustic alkali and bleaching powder and would then stop, for that is the only electrochemical process at present installed at "the Soo." With the indulgence of the reader, we will therefore digress from the straight and narrow way and use the above title as a text under which we will speak of the general situation of Sault Ste. Marie, its facilities for manufacturing and its potentialities in the electrochemical line.

First, as to the power there available, the St. Mary River is the outlet of Lake Superior, which, with its 30,000 square miles of surface, is the largest body of fresh water on the earth. The river runs over rapids about half a mile long, with a total fall of 20 feet. This head is made available by constructing canals around the rapids, and thus conducting the water to power houses below them. The discharge varies with the season and the winds, but is, at its lowest, 3,600,000 cubic feet per minute, representing a total of 135,000 horse-power. This is, however, to be diminished by the loss in conversion into mechanical and electric power, and by the fact that, in order to give flow through the intake canals, some of the head must be sacrificed, and only 18 feet of head can be counted on at the power houses. Allowing for these, the minimum available electric power of Sault Ste. Marie is about 110,000 horse-power. More than this might be generated at times, but it will hardly pay to install a power plant in excess of this, part of which would either be idle or run at only a fraction of its capacity for part of the year.

The present utilization of the power includes a 20,000 horse-power house on the Canadian side, owned by the Lake Superior Power Co., and a 40,000 horse-power plant on the American side, owned by the Michigan Lake Superior Power Co., so that 60,000 of the possible 110,000 horse-power is already taken care of.

The American plant has just been completed. The water-power canal is over two miles long, and traverses the city of Sault Ste. Marie, Mich. It is 200 feet wide, 25 to 27 feet deep, cut partly through red sandstone rock and partly through red clay, and will be capable of delivering some 20,000 cubic feet of water per second. It was an expensive canal to construct, the bottom being in places planked over to avoid scouring, and eight steel bridges being necessary where it crossed streets. The power house is on the river edge, and is 1,340 feet long, 87 feet wide and 107 feet high, built in a most substantial manner of sandstone, on pile foundations. It is divided into 80 divisions, to each of which is a set of four 125 horse-power turbine wheels, actuating a 500 horse-power dynamo on the floor above. Current for near-by industries will be generated at low voltage and of the amperage needed; for distant use it will be transmitted at high voltage. The canal cost $3,000,000, the power house, with docks and equipment, $1,000,000, making a total cost of $4,000,000. If we estimate the interest which this money should earn at 10 per cent., the cost of maintenance and labor at 2½ per cent. and depreciation at 2½ per cent., the price which this power should command, as electrical horse-power, is about $15 per horse-power per year. The statements are made officially that industries which contract for this power at $20 per horse-power per year will be furnished sites free, and will be exempted from borough taxation for five years; but unofficial statements are current to the effect that some of this power may be had for prices nearer to $10 per horse-power per year than $20.

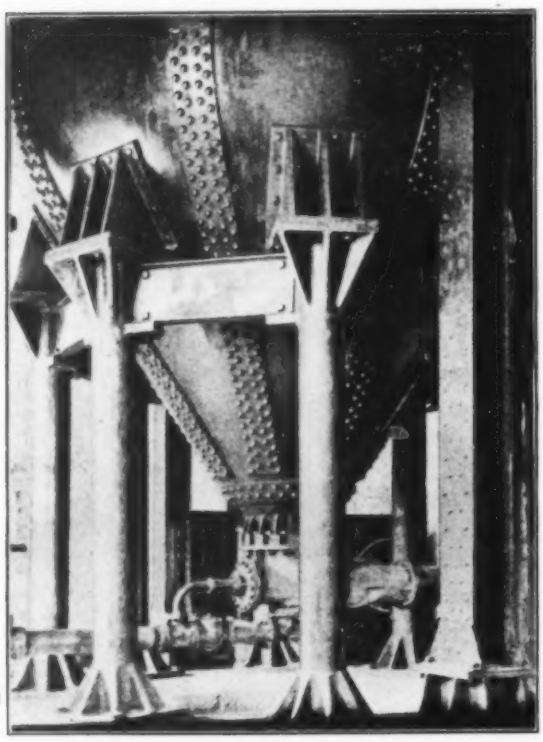
GENERAL VIEW OF THE CANADIAN SIDE.

Showing from the left to the right the Canadian Electrolytic Alkali Co., the power house, wood pulp mill, sulphite pulp mill, iron foundry and office building.

The Canadian plant is situated alongside of the Canadian lock, and, with a 100-foot wide canal, is generating at present 20,000 horse-power. This power is almost all in use, the larger part being taken by the Sault Ste. Marie Pulp and Paper Co., who have the largest ground wood pulp mill in the world, having a capacity of 150 tons of dry pulp and 75 tons of bleached sulphite pulp per day. An interesting combination is the installation of a roasting plant to roast nickel ores from the company's nickel mines at Sudbury. This is placed alongside the wood pulp mill, and the sulphur dioxide gas generated by roasting the ore is passed directly to the pulp mill and there used for bleaching and gelatinizing the pulp in connection with

the lime hyposulphite. An iron foundry and a large machine shop use also considerable power. The power plant and buildings are finely and substantially built, and there is plenty of land in the vicinity for new industries.

About a mile further up the river is a new steel plant, consisting of a large plant of charcoal by-product ovens for obtaining charcoal from hardwood and saving the acetic acid and wood spirit, two blast furnaces—one for making charcoal iron, the other to use coke—and a Bessemer steel mill, with a capacity of 600 tons per day. At these mills the first steel rails rolled in Canada were made, and, since the Canadian Government pays a bounty of $3 per ton on all pig iron made from ore mined in Canada, and an additional bounty of $5 per ton on all steel made in Canada, there should be no doubt as to the profitable operation of this modern plant.



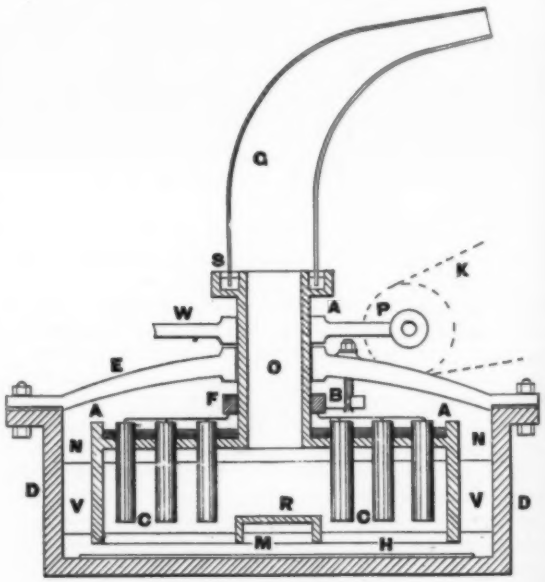
DIGESTER, SULPHITE TULP MILL.
65 ft. high, 17 ft. diameter.

The Rhodin process for making caustic alkali is the only electrochemical process now located at Sault Ste. Marie, and we will describe it at length. Before doing so, however, we will note the statements which are made that 10,000 horse-power on the American side is already contracted for, for the manufacture of calcium carbide, by the Union Carbide Co., and 5,000 horse-power for extensions of the Rhodin process; while it is further contemplated to establish electrolytic plants for refining Lake Superior copper and Sudbury nickel. It is possible that some of these propositions will materialize. Calcium carbide is in very extensive use in Western Canada, as was observed by the writer on a recent trip from Victoria, B. C. The consumption of this chemical is bound to increase largely, as the acetylene light is so well suited to the conditions prevailing in that vast territory. Lake Superior copper can be refined in transit towards the Eastern markets very advantageously at this point, and the same applies to the Sudbury nickel. It is true that navigation is closed for five months of the year, but the railways centering there have given through freight rates to Chicago and other points, which are so low as to practically annul this disadvantage and make the railway transportation as cheap as the water rates all the year around. This statement was made to the writer by Mr. F. J. Clerque, general manager of the Clerque Syndicate, and is therefore official.

The Canadian Electrochemical Co., Ltd., rent power from the Lake Superior Power Co., on the Ontario side, and are installed in buildings owned by that company, close to the Canadian lock. They use the Rhodin process of electrolyzing sodium chloride solution and obtaining caustic soda and bleaching powder. When visited by the writer, September 12th last, they were not in operation, because the war between the chemical and electrochemical alkali companies in Europe had so demoralized the market for the products (bleaching powder being sold by them in Canada as low as $20 per ton) that the plant could not be operated profitably at the low prices.

The installation to be described was considered by the company as a more or less experimental one, which would develop into a large plant on the American side. But while the power for the latter has been contracted for, the company have been unable to take any steps towards erecting that plant, because of financial difficulties, too little of the capital stock of the company having been realized as available cash for erecting the plant. It is hoped that a financial reorganization of the company will enable the American plant to be commenced in the near future.

The Canadian plant consists of three 350 horse-power turbines, each actuating a 200-kilowatt dynamo. Each dynamo runs a row of 40 decomposing cells, connected in series. The current in one circuit is 900 ampères, and the total potential at the dynamo is 220 volts, which, allowing the extra 20 volts for the resistance of the conductors and connections in the circuit, leaves an average drop of 5 volts per cell. The theory of the action of the cell is the decomposition of concentrated brine between graphite anodes and a layer of mercury in a large iron pan as cathode, the anodes being contained in a bell-shaped vessel, which collects and carries away the evolved chlorine, while the mercury charged with sodium escapes under the lip of the bell and passes into the space outside, where, coming into contact with water, it discharges its sodium and produces caustic alkali solution. Mechanical arrangements produce a rotation of the bell, the continuous inflow and outflow of brine therefrom and a continuous or intermittent supply of water to the pan outside the bell.



RHODIN CELL.

The annexed diagram of the cross section of the cell shows the mechanical details. D is the cast-iron pan, 5 feet in diameter by 1 foot deep, containing a layer of mercury, H, which can scarcely be less than 1 inch in depth, which would imply at least 1,000 pounds weight of mercury in each cell, costing, at current prices, $600. This item will then constitute one of the largest items of cost of the plant. Suspended inside this pan is an inverted earthenware bell, A, 3 feet in diameter, through the top of which pass the graphite anodes, C, which reach down to within 1 inch of the mercury. These carbons are fastened into the holes by pouring cement around them, and are in electrical connection with the copper ring, F, to which the current is conducted by a brush, B.

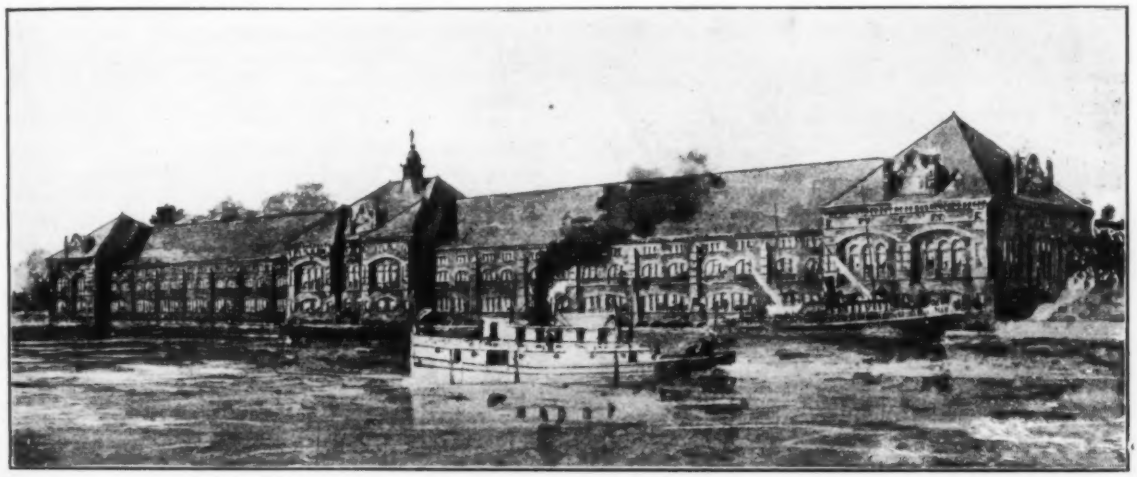
The inside of the bell, sealed off from the outside by its edge dipping beneath the mercury, is partly filled with concentrated brine solution. This is renewed continuously by inlet and overflow outlet pipes passing through the botom of the pan. The fresh brine is fed directly into the field of decomposition, between the carbons and the mercury. The bell is supported by a framework across the top of the iron cell, and has an upward prolongation or tube through which the chlorine escapes. To make connection with the stationary chlorine pipe, the latter dips into a circular water-seal on top of the prolongation, as shown in the cut at S. The bell is rotated by a worm and gear, thus bringing the carbon anodes continually over fresh surfaces of mercury. The brine is thus given a rotary movement also, which further imparts itself to the mercury, and the latter, by means of radial grooves in the bottom of the iron pan, is by that means continually forced towards the outer edge of the pan.

Outside of the bell there is water resting upon the mercury, which acts upon the amalgam and produces caustic soda, with liberation of hydrogen. This solution is allowed to stay until it becomes quite strong, and is then run off by a siphon pipe and replaced by fresh water. It was stated by the inventors that the iron pan was heated externally to nearly the boiling point of the solutions, resulting in preventing the brine keeping so much chlorine in solution and increasing the efficiency of discharge of the amalgam, as also reducing the electrical resistance of the cell. This information, however, was altogether at fault, for above 75 degrees chlorate is formed in large quantity, destroying the anodes and causing great danger of explosions from the admixture of oxygen with the chlorine. The real facts are that the passing of 900 ampères through such a cell, 3 feet in diameter, heats the liquid by its own resistance much more than is desirable, and the problem is rather how to keep the cell cool than to heat it.

The theoretical difference of potential required to decompose a saturated brine solution and to form sodium and set free chlorine is $\frac{97200}{23040} = 4.22$ volts. The absorption of the sodium to form amalgam, however, gives out considerable energy, which is returned as e. m. f. to the circuit; this amounts to $\frac{21600}{23040} = 0.89$ volt. The voltage absorbed in decomposition is therefore 3.33 volts. The actual voltage used to force 900 ampères through is 5 volts, which leaves, therefore, 1.67 volts absorbed in overcoming ohmic resistance, and represents electrical energy converted into heat. This is equivalent to a generation of about 45 pound calories of heat per minute in the apparatus, sufficient to heat it and its contents about 20° F. in an hour if no heat were radiated. We see that it is therefore quite likely that the apparatus will rush some 20° F. above the outside room temperature simply from the heating effect of the current.

In such an apparatus it is likely that there will be some loss by re-combination of sodium in the anode compartment. There is no positive removal of the amalgam from the bell, neither is there a positive method of discharging it outside. These two operations take place at their own pace, so to speak, and therefore will lag behind the charging action with such a heavy current. Mr. Rhodin has stated the loss by re-solution at the brine surface as 3 per cent. It might have been anticipated as still larger. The discharge is voltaic in its nature, for the iron pan and amalgam form a short-circuited voltaic couple, which, when moistened by the water, causes the discharge of the sodium and the evolution of hydrogen from the iron. This action differs from the Kellner method of discharging amalgam, in that the latter uses a distinct cathode plate in the caustic solution, separated from and not in physical contact with the amalgam, and thus constituting a galvanic cell, of which the amalgam is one pole and the wire from the cathode plate the other pole, and from which a useful galvanic current can be extracted and utilized, as Kellner utilizes it in his German patent, in assisting the main current used for decomposition in the cell or for any other exterior purpose.

With the voltaic couple action of Rhodin there is no usefully available e. m. f. generated, and the whole energy of decomposition of the amalgam, representing one-fifth of the whole current energy used in the apparatus, heats up the caustic soda solution, and thus increases the temperature of the apparatus. Using Kellner's or Castner's arrangements, whereby the galvanic e. m. f. of this cell is restored to the circuit, only as much of this energy is converted into heat in the caustic solution as is necessary to overcome the ohmic resistance between the cathode and anode in this solution,



MICHIGAN POWER BUILDING.

which, with properly-shaped cathodes, should be *less* than the galvanic e. m. f. of the cell.

The whole installation consists of 120 of these cells, but only 80 have been in operation at once. The bleaching-powder plant consists of 10 chambers, each 55 feet 6 inches long, 17 feet wide and 6 feet 6 inches high, made of No. 6 sheet lead, and with a 2-inch tile floor. The lime plant can furnish 14 tons of slaked lime daily. With 80 cells in operation, the output was 4.4 tons of bleaching powder and 2 tons of caustic daily. This represents about 80 per cent. of the theoretical output for the current used.

The salt used contained 99.5 per cent. of sodium chloride, the rest being mostly calcium and sodium sulphates. These and the free chlorine cause about 1-20 of 1 per cent. of mercury to go into the brine, but, as the solution is used over and over, this causes no loss, except when the brine is changed because of becoming impure, and then, every three or four weeks, about 20 pounds ($14 worth) is lost. In the alkali solution one pound of mercury (worth 70 cents) is dissolved for every 27,500 pounds of caustic produced. This loss is therefore negligible from a commercial standpoint.

If the whole 120 cells were operated, the 4 tons of caustic soda and 9 tons of bleaching powder which it would produce daily would supply all of the latter consumed in Canada and a considerable proportion of the former, but at present market prices in Canada, without a protective tariff, the plant cannot be profitably operated.

THE THALLIUM STORAGE CELL.

By A. L. Marsh.

THE oxides of thallium are possessed of properties which place them in a new class of electrode materials. The lower oxide, thallous oxide (Tl_2O), is soluble in water, while the higher oxide, thallic oxide (Tl_2O_3), is insoluble in water and in potassium hydroxide solutions. No other metal forms oxides which bear to each other the above relations. Silver, perhaps, comes the nearest, but differs in that its lower oxide is only very slightly soluble in water.

Thallic oxide in a hydrated state is an almost black compound, resembling lead peroxide. It is a conductor of electricity, and is deposited on the anode from alkaline solutions, just as lead peroxide is deposited from a nitric acid solution. Thallous oxide, or rather the hydroxide (TlOH), is very soluble in water, and is a more stable compound than the thallic oxide. Metallic thallium can be readily deposited from its water solutions by the electric current. In ease of deposition, it stands near the metals lead and cadmium. Here we have the essential features of the thallium cell: For the negative, a metal which may be easily deposited from its water solutions; an electrolyte of thallous hydroxide (TlOH) which is the product of oxidation at the negative or reduction at the positive; and for the positive thallic oxide, an easily-reducible compound, a conductor of electricity, and capable of being deposited on the anode from an alkaline solution.

In charging a cell using a thallous oxide electrolyte, both the positive and the negative active materials are formed from the electrolyte, while on discharging the cell the process is reversed; the materials at both electrodes return to their original condition as electrolyte. There are only two oxides of thallium known, and these, together with the metallic condition, constitute the exact number of chemical changes necessary to the storage of electrical energy in the form of chemical energy in the so-called storage battery. Many metals, under a given set of conditions, are capable of a number of changes in excess of the required number, and therefore introduce complications.

Thallium was discovered in 1861 by Crookes, with the aid of the spectroscope. In examining some seleniferous flue dust from a sulphuric acid manufactory in the Hartz Mountains, Germany, a bright green line was discovered in the spectrum, and the new element was given the name thallium, which is derived from the Greek word meaning "green," or "a young shoot." The honor of having isolated the metal and establishing its true character belongs to Lamy.

The element occurs in small quantities, but is widely distributed in Spanish and Belgium pyrites.. In some of these ores the quantity of thallium reaches as high as 3.5 per cent. It is also found in certain mineral waters, and in some specimens of mica and lepidolite. Mother liquor from zinc works in the Hartz Mountains contains about .05 per cent. of thallium. A rare Swedish mineral called Crookesite contains as high as 18 per cent. of this metal. Its chief source at present is the flue dust of sulphuric acid works.

The metallurgy of thallium is comparatively simple. The flue dust is extracted with water, and the thallium precipitated as thallous chloride (TlCl) with hydrochloric acid. This is dissolved in sulphuric acid, and from the resulting solution metallic thallium is precipitated by metallic zinc or by electrolysis.

Thallium bears a great resemblance to lead. It has a silver-like luster at a freshly-cut surface, but tarnishes rapidly in the air. It is malleable, but not ductile. Its specific gravity is 11.8; specific heat, .0325; melting point, 294° C.; atomic weight, 204. Nitric and sulphuric acids dissolve the metal readily, but hydrochloric acid has little action upon it. Surfaces of the metal exposed to the air become yellowish. The yellowish film readily dissolves off in water, and the surface regains its metallic appearance.

There are two series of compounds, the thallous, in which thallium is monovalent, and the thallic, in which the metal is trivalent. Thallous oxide (Tl_2O) is a black compound, formed by heating the hydroxide (TlOH) to 100° C. in such a manner as to avoid further oxidation. The hydroxide is formed by exposing the metal to the action of air and water or by adding baryta water (barium hydroxide solution) to a solution of the sulphate. $Tl_2SO_4 + Ba(OH)_2 = BaSO_4 + 2TlOH$. Barium sulphate is a white precipitate, and thallous hydroxide remains in solution. From a concentrated solution crystals having the composition $TlOH, 2H_2O$ are deposited.

Thallic oxide (Tl_2O_3) may be prepared by burning the metal in oxygen. By adding a solution of sodium hypochlorite to thallous chloride, a brown precipitate is formed, having the formula $Tl(OH)_3$ (thallic hydroxide). By electrolysis of a solution of thallous oxide, black thallic oxide is deposited on the anode, probably in the form of a hydrate. Having now described the occurrence, properties and compounds of thallium, we will describe the thallium cell more in detail.

A cell was constructed as follows: A small glass vessel was partly filled with a dilute solution of thallous oxide, to which about 10 per cent. of potassium hydroxide was added to increase the conductivity. Electrodes of thin sheet iron, about 1 inch square, were covered with the electrolyte, and the cell was closed with a cork stopper. Upon sending a current of about one-quarter ampère through the electrolyte, spongy thallium separated on the cathode and thallic oxide on the anode. The thallic oxide deposited in a hard black coating, which had a tendency to scale off in places as the layer increased in thickness. There was no gasing, even when the current density was considerably increased. When the charging current was stopped and the cell short-circuited through a galvanometer, comparatively large currents could be obtained. No instrument was at hand for accurate measurement of the electromotive forces. However, indications were that it was little more than .5 volt.

The theoretical storage capacity of thallium and its oxides is very low, the value for thallic oxide being about 53.2 ampère hours per pound, and that for metallic thallium, used as the negative, about 59.5 ampère hours per pound. The corresponding figures for lead peroxide and metallic lead being respectively 101.6 and 117.3 ampère hours per pound, those for silver peroxide (AgO), positive and metallic iron negative, are respectively 195.7 and 433.3 ampère hours. While the theoreti-

cal capacity of thallium and its compounds is extremely low, yet it is much higher than has been obtained in practice by the use of any metal.

Comparing the thallium cell with the lead type, we find the following points of difference:

1. In the lead cell the active materials, both positive and negative, are insoluble* throughout the cycle of changes. In the thallium cell the active materials at both poles are insoluble during the charged state, and both soluble in the electrolyte when discharged.

2. The active material of the lead cell being insoluble when discharged, the charged or peroxidized particles are soon surrounded by the products of discharge, and a large proportion of the peroxide mass is prevented from taking part in the discharge, so a large proportion of the plate is inactive or is dead weight. In the thallium cell, as fast as the peroxide is reduced by discharge, the resulting compound goes into solution, and so leaves the remaining material fully exposed to further action.

3. With lead electrodes, the active material is securely fixed in a suitable grid once for all, while with the thallium cell unattacked sheets of metal suspended in the electrolyte receive a deposit at each charge and lose it at every discharge.

4. With the lead cell, the electrodes must undergo a forming process before they are ready for service, while with the thallium cell no such process is necessary.

5. In lead cells gasing occurs more or less throughout charge, and becomes violent towards the end. No gasing occurs in the thallium cell, unless it is at the end of charge, when the action has been carried too far and the electrolyte has been exhausted of thallous oxide.

6. In the lead cell, the active materials not being deposited from the solution, there is not introduced the difficulty of obtaining compact, evenly distributed and adherent deposits, that gives so much trouble in the thallium cell and in all others having soluble products.

7. The lead cell gives a high electromotive force, while the thallium cell gives a low one.

8. The voltage must not fall below 1.6 in the lead cell, while in a cell of the thallium type a discharge to 0 voltage ought to do no harm.

9. The theoretical storage capacity of lead is nearly twice as high as that of thallium.

10. The cost of construction is more for the lead cell than for the thallium cell, owing to the preparation and formation of the plates in the former case.

11. The first cost of materials is low in the case of the lead cell, while it is comparatively high for thallium.

The thallium cell makes use of a metal generally considered to be rare. While it most frequently occurs in small quantities, it is quite widespread, being found in many pyritic zinc ores. The price of this metal is about $6 per pound. To show the possibilities of some of the rare metals for storage-battery purposes, as far as cost is concerned, I quote from the "Mineral Industry," Vol. VIII, a statement by Mr. Victor Lenher:

"It should be remembered that while a use has been found for many of the rare and high-priced elements, there are many more that owe their present market price only to the fact that the demand is limited to specimens for museums or to the small amounts that are needed for research work. For example, in 1895 thorium nitrate sold at $200 a pound, while to-day it can be bought in Germany for $3.33 per pound."

Even a reduction in price to a few dollars per pound might seem at first thought to be a prohibitively high price for a metal to be used in storage batteries, when lead and its oxides can be bought for a few cents a pound. However, this is not necessarily so, if the metal possesses properties specially adapted to storage work. For instance, a battery using a material which insures a long life with hard usage, can be easily utilized again without excessive waste, requires no tedious forming process for its preparation, gives a high capacity, a high electromotive force and a high efficiency, and is capable of retaining a charge for a reasonable length of time, would admit of using a metal whose cost is many times greater than the cost of lead.

High capacity is a very important factor, since the higher the capacity the smaller the amount of material required.

No metal has yet been found that meets all these requirements, or even the greater part of them. Thallium is lacking in many important points, but at the same time possesses some good features. In the first place, a great objection is the fact that it is a difficult matter to obtain good, evenly distributed, coherent and adherent deposits of metal or of peroxide. The peroxide is particularly troublesome, on account of its peeling off the electrode. Otherwise this type of cell would have a decided advantage, in that a fresh surface of active material is always exposed as the discharge proceeds, a large proportion of the material may be utilized and the discharge may be allowed to proceed to 0 voltage. The fact that in the thallium cell the active materials of both electrodes are formed from the electrolyte, and when discharged return to their original condition as electrolyte, ought to be a strong point in favor of long life, for, the electrodes being permanent, the difficulty would be temporary, and could be corrected by properly charging. Each charge is practically the same as putting in new electrodes in the lead cell.

Since the thallium is in solution as the oxide in one part of the cycle makes it easy to utilize the material from worn-out cells. Thallium compounds are easily manipulated chemically.

The fact that the discharge product is soluble in the electrolyte obviates the use of a special forming process. In the matter of capacity, thallium stands very low in the scale; low also in regard to the electromotive force it is capable of producing. Efficiency is a matter not yet determined, but it would probably be low, for the reason that it is difficult to obtain good deposits on the electrodes. There would probably be no difficulty in the retention of charge.

It is obvious that thallium is not a metal from which a practical battery could be developed, not so much on account of its high cost as on account of its non-adaptability to the purpose. Yet the thallium cell should be interesting from a scientific standpoint, from the fact that its higher oxide represents a new type of positive electrode material.

* Here, all metals are considered to be insoluble in water or acids. In a strict sense, metals are not soluble in water or acids, but products may result which are soluble in these media.

ANNUAL MEETING AMERICAN ELECTROCHEMICAL SOCIETY.

At the meeting of the Board of Directors of the American Electrochemical Society, held on November 6th, it was decided that the next general meeting will be held in New York City, on Thursday, Friday and Saturday of the week following Easter Sunday, *i. e.*, April 16, 17 and 18, 1903. On Thursday, April 16th, the annual business meeting will be held, at 10.30 A. M., when the results of the election of officers will be announced. The program for the other days has not yet been arranged.

The suggestion to hold in autumn a meeting in Sault Ste. Marie, simultaneously with the meeting of the American Institute of Electrical Engineers, was favorably looked upon, but no definite decision has yet been reached.

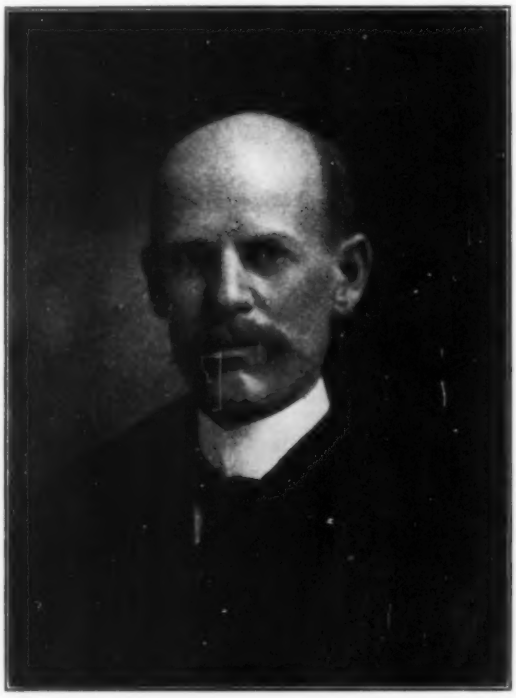
There appears to be a difficulty in arranging this simultaneous meeting, because the American Institute of Electrical Engineers have usually held their annual summer meeting in the early summer, generally in June. On the other hand, it would be impossible for the American Electrochemical Society to hold again a general meeting in June, so shortly after the annual business meeting, which must be held in March or April, according to the constitution.

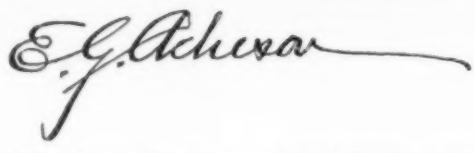
PIONEERS OF ELECTROCHEMISTRY—III.

Edward Goodrich Acheson.

Edward Goodrich Acheson was born in Washington, Pa., March 9, 1856. His education was received at the Bellefonte Academy, Bellefonte, Pa., he finding it necessary to leave in 1872, before completing his course. Immediately after leaving school he joined a civil engineer corps on railroad construction as chainman, and followed this line of work for several years, eventually rising to the position of transit-man.

Acheson had always exhibited an intense interest in scientific subjects, and followed with great interest the newspaper descriptions of Edison's work at Menlo Park, being finally so captivated with electrical studies that he determined to seek a position in that line of scientific work. He was at that time living in the Pennsylvania oil fields at Bradford, in the employ of the Standard Oil Co. He resigned this position, and some little time later arrived in New York City and made application to Mr. Weston, at Newark, N. J., for a position. Failing there, he applied to the Western Electric Co., New York, and in turn several other of the early electrical establishments of that day, finally going to Menlo Park, where he was fortunate in securing employment in Mr. Edison's laboratory in the capacity of draftsman. Mr. Edison seems to have quickly appreciated his worth, and promotion following, he was within two months in charge of original experimental work in the laboratory.





Acting on Mr. Edison's advice, Acheson gave particular attention to the manufacture of the new incandescent lamp, and on July 20, 1881, he was sent to Europe as assistant engineer of the Edison interests abroad. His first duties in the new field were more or less of an official character in the electrical exhibition at Paris, 1881. At the close of the Exposition he was given charge of, and constructed, the installation of the lamp factory in Edison's plant at Irvy-sur-Seine. He later was sent out on a trip through Europe, installing lighting plants at Milan, Pisa, Brussels, Bergamo, Geneo, Antwerp and many other places. Several Edison companies were formed as the result of this tour. Acheson left the Edison interests about the beginning of 1883, and took up private experimental work on electric batteries and thermopiles, the results of which were not satisfactory.

Returning to the United States in January, 1884, Acheson renewed his connection with the Edison interests, but shortly afterwards he again became engaged in private experimental work, which having been carried on for some few months, he accepted the position of superintendent of the Consolidated Lamp Co. of Brooklyn, with whom he remained but a few months, once more returning to his private experimental work on the conversion of heat energy into electrical energy. In 1886, he was appointed electrician of the Standard Underground Cable Co., of Pittsburg, and after filling this position for three years, he resigned and once more returned to private experimental field. In order to have greater facilities with which to carry on his experiments, Acheson organized a local electric-light plant at Monongahela, Pa., which began operations November 20, 1890. With the large power and many facilities at hand, a great variety of experiments were undertaken, one made in March of 1901 resulting in the production of that now well-known material "carborundum." Acheson had made an experiment in Edison's laboratory in the winter of 1880, which was productive of a substance of remarkable hardness, and at that time it occurred to him that it might be of value as an abrasive material. After a lapse of more than ten years, he made the experiment of mixing clay and carbon together, placed it in an iron bowl which was connected with one terminal of his dynamo, and, embedded in the mixture, he placed an arc light carbon, which was connected with the other terminal of the dynamo. A sufficient current to raise the mixture to a high temperature having been passed for some time, Acheson observed a few bright blue and black crystals attached to and surrounding the carbon rod. These crystals he named carborundum, and immediately began its manufacture in a small way. His production for the following six months amounted to about ¼ pound per day, and the material was sold to the lapidaries and machinists for grinding purposes.

The preliminary experiments in the manufacture proving encouraging, a stock company was organized in the fall of the same year, under the title "The Carborundum Co.," and they began operations at Monongahela City. In 1894, the large power development of Niagara Falls approaching completion, Acheson decided to establish a large plant at that place, but his stockholders were unwilling to subscribe to such movement, and Acheson, having disposed of a number of his patents in Enrope, used his own means for the construction of a large modern plant at Niagara Falls. After this plant was in operation, carborundum was produced in large quantities and was correspondingly cheaper in price, but still so much more expensive than emery that the emery-wheel makers refused to buy the material, and it was forced upon the company to enter into the manufacture of carborundum goods. The three years following were devoted to perfecting the manufacture, not only of carborundum, but of the articles made from it, and the material made rapid advancement in its applications to the various arts, in many instances entirely supplanting the emery goods. During this period there was added to the plant a department for the manufacture of carborundum paper and cloth, this proving equally as successful as the other lines of manufacture. It is interesting to note that the first sale of carborundum in 1891 was 200 carats, at 30 cents per carat, or $560 per pound, while in 1901 the output was 3,838,000 pounds, sold at an average price of 10 cents per pound.

Finally, in 1897, the carborundum problems having been com-

pletely solved and the opening of a market well started, Acheson turned his attention to the manufacture of graphite from amorphous carbon. In the manufacture of carborundum, some of that material was occasionally decompsed, owing to excessively high temperatures, and he noticed that a fine flake graphite was left as a result of the decomposition. Carborundum, or—to use its chemical name—silicon carbide, containing equal atomic proportions of the two elements of which it was composed, Acheson recognized that by heat they could be separated, the silicon volatilizing and the carbon secured as graphite. He took out patents protecting this method of manufacturing graphite, and after some further experimenting entered upon its commercial manufacture. A stock company was formed, called the Acheson Graphite Co., which was later absorbed by a new organization, the International Acheson Graphite Co. In 1891 this company produced about 2,500,000 pounds of graphite, of which 1,100,000 pounds were in the form of graphite electrodes. These electrodes have proved of great assistance in the development of electrochemical industries, as graphite in this form has been found to give excellent results.

Too much credit cannot be given the man who with so much self-sacrifice and perseverance built up these two industries to their present substantial footings. Although he met with many failures and disappointments, he was at no time discouraged and always took up the work with renewed determination.

Mr. Acheson has received several medals for his work, among which may be mentioned the following: Two medals from the Franklin Institute—one being for carborundum and the other for graphite; a gold medal from the World's Columbian Exposition, for carborundum; a gold medal from the Trans-Continental Exposition at Omaha, for carborundum and graphite; a gold medal from the Pan-American Exposition, at Buffalo, for the same; and a grand prix at Paris Exposition, 1900, for an exhibit of carborundum and graphite.

Mr. Acheson is a member of the American Institute of Electrical Engineers; American Association for the Advancement of Science, and a manager of the American Electrochemical Society.

LOW TEMPERATURE RESEARCHES.*

BY JAMES DEWAR,

President of the British Association for the Advancement of Science.

HISTORY OF THE RESEARCHES ON THE ABSOLUTE ZERO POINT OF TEMPERATURE.

THE nature of heat and cold must have engaged thinking men from the very earliest dawn of speculation upon the external world, but it will suffice for the present purpose if, disregarding ancient philosophers, and even mediæval alchemists, we take up the subject where it stood after the great revival of learning, and as it was regarded by the father of the inductive method. That this was an especially attractive subject to Bacon is evident from the frequency with which he recurs to it in his different works, always with lamentation over the inadequacy of the means at disposal for obtaining a considerable degree of cold. The great Robert Boyle was the first experimentalist who followed up Bacon's suggestion. In 1682 Boyle read a paper to the Royal Society on "New Experiments and Observations Touching Cold, or an Experimental History of Cold," published two years later in a separate work. This is really a most complete history of everything known about cold up to that date, but its great merit is the inclusion of numerous experiments made by Boyle himself on frigorific mixtures and the general effects of such upon matter. The agency chiefly used by Boyle in the conduct of his experiments was the glaciating mixture of snow or ice and salt. In the course of his experiment he made many important observations. Thus he observed that the salts which did not help the snow or ice to dissolve faster gave no effective freezing. He showed that water in becoming ice expands by about one-ninth of its volume and bursts gun barrels. He attempted to counteract the expansion and prevent freezing by completely filling a strong iron ball with water before cooling, anticipating that it might burst the bottle by the stupendous forces of expansion, or that if it did not, then the ice produced might, under the circumstances, be heavier than water. He speculated in an ingenious way on the change of water into ice. Thus he says: "If cold be but a privation of heat through the recess of that ethereal substance which agitated the little eel-like particles of the water, and thereby made them compose a fluid body, it may easily be conceived that they should remain rigid in the postures in which the ethereal substances quitted them, and thereby compose an unfluid body like ice. Yet how these little eels should by that recess acquire as strong an endeavor outwards, as if they were so many little springs, and expand themselves with so stupendous a force, is that which does not so readily appear." The greatest degree of adventitious cold Boyle was able to produce did not make air exposed to its action lose a full tenth of its own volume, so that, in his own words, the cold does not "weaken the spring by anything near so considerable as one would expect." After making this remarkable observation and commenting upon its unexpected nature, it is strange Boyle did not follow it up. He questions the existence of a body of its own nature supremely cold, by participating in which all other bodies obtain that quality, although the doctrine of a *primum frigidum* had been accepted by many sects of philosophers. The whole elaborate investigation cost Boyle immense labor, and he confesses that he "never handled any part of natural philosophy that was so troublesome and full of hardships." He looked upon his results but as a "beginning" in this field of inquiry. After the masterly essay of Boyle, the attention of investigators was chiefly directed to improving thermometrical instruments. The old air thermometer of Galileo being inconvenient to use, the introduction of fluid thermometers greatly aided the inquiry into the action of heat and cold. For a time great difficulty was encountered in selecting proper fixed points on the scales of such instruments, and this stimulated men like Huygens, Newton, Hooke and Amontons to suggest remedies and to conduct experiments. By the beginning of the eighteenth century the freezing point and the boiling point of water were agreed upon as fixed points, and the only apparent difficulties to be overcome were the selection of the fluid, accurate calibration of the capillary tube of the thermometer and a general understanding as to scale divisions. It must be confessed that great confusion and inaccuracy in temperature observations arose from the variety and crudeness of the instruments. This led Amontons, in 1702-1703, to contribute two papers to the French Academy which reveal great originality in the handling of the subject, and which, strange to say, are not generally known. The first discourse deals with some new properties of the air and the means of accurately ascertaining the temperature in any climate. He regarded heat as due to a movement of the particles of bodies, though he did not in any way specify the nature of the motion involved; and as the general cause of all terrestrial motion, so that in its absence the earth would be without movement in its smallest parts. The new facts he records are observations on the pressure of air brought about by the action of heat. He shows that the ratio of the total pressure of air at two definite and steady temperatures and at constant volume is a constant, independent of the mass or the initial pressure of the air in thermometer. These results led to the increased perfection of the air thermometer as a standard instrument, Amontons' idea being to express the tempera-

* Presidential Address, delivered at the recent Belfast meeting of the British Association for the Advancement of Science. (Lack of space requires the omission of the introductory remarks of the address; the historical notes in the chapter on the "History of the Researches on the Absolute Zero Point of Temperature" have also been slightly abridged. —Ed.)

ture of any locality in fractions of the degree of heat of boiling water. The great novelty of the instrument is that temperature is defined by the measurement of the length of a column of mercury. In passing, he remarks that we do not know the extreme of heat and cold. In the following year Amontons contributed to the Academy a further paper extending the scope of the inquiry. He there pointed out more explicitly that as the degrees of heat in his thermometer are registered by the height of a column of mercury, which the heat is able to sustain by the pressure or "spring" of the air, it follows that the extreme cold of the thermometer will be that which reduces the air to have no power of spring. This, he says, will be a much greater cold than what we call "very cold," because experiments have shown that if the "spring" of the air at boiling point is 73 inches, the degree of heat which remains in the air when brought to the freezing point of water is still very great, for it can still maintain the spring of 51½ inches. The greatest climatic cold on the scale of units adopted by Amontons is marked 50, and the greatest summer heat is 58, the value for boiling water being 73 and the zero being 52 units below the freezing point. Thus Amontons was the first to recognize that the use of air as a thermometric substance led to the inference of the existence of a zero of temperature, and his scale is nothing else than the absolute one we are now so familiar with. If we adopt the Celsius scale of temperature, then the zero of Amontons' air thermometer is *minus* 240 degrees. This is a remarkable approximation to our modern value for the same point of *minus* 273 degrees. It has to be confessed that Amontons' valuable contributions to knowledge met with that fate which has so often for a time overtaken the work of too-advanced discoverers. In other words, it was simply ignored, or, in any case, not appreciated by the scientific world, either of that time or half a century later. It is not till Lambert, in his work on "Pyrometrie," published in 1779, repeated Amontons' experiments and indorsed his results that we find any further reference to the absolute scale or the zero of temperature. Lambert's observations were made with the greatest care and refinement, and resulted in correcting the value of the zero of the air scale to *minus* 270 degrees, as compared with Amontons' *minus* 240 degrees. Lambert points out that the degree of temperature which is equal to zero is what one may call absolute cold, and that at this temperature the volume of the air would be practically nothing. In other words, the particles of the air would fall together and touch each other and become dense like water; and from this it may be inferred that the gaseous condition is caused by heat. Lambert says that Amontons' discoveries had found few adherents, because they were too beautiful and advanced for the time in which he lived.

About this time a remarkable observation was made by Professor Braun at Moscow, who, during the severe winter of 1759, succeeded in freezing mercury by the use of a mixture of snow and nitric acid. When we remember that mercury was regarded as quite a peculiar substance, possessed of the essential quality of fluidity, we can easily understand the universal interest created by the experiment of Braun. This was accentuated by the observations he made on the temperature given by the mercury thermometer, which appeared to record a temperature as low as *minus* 200° C. The experiments were soon repeated by Hutchins at Hudson's Bay, who conducted his work with the aid of suggestions given him by Cavendish and Black. The result of the new observations was to show that the freezing point of mercury is only *minus* 40° C., the errors in former experiments having been due to the great contraction of the mercury in the thermometer in passing into the solid state. From this it followed that the enormous natural and artificial colds which had generally been believed in had no proved existence. Still the possible existence of a zero of temperature very different from that deduced from gas thermometry had the support of such distinguished names as those of Laplace and Lavoisier. In their great memoir on "Heat," after making what they consider reasonable hypotheses as to the relation between specific heat and total heat, they calculate values for the zero, which range from 1,500° to 3,000° below melting ice. On the whole, they regard the absolute zero as being in any case 600° below the freezing point. Lavoisier, in his "Elements of Chemistry," published in 1792, goes further in the direction of indefinitely lowering the zero of temperature. Even as late as the beginning of the nineteenth century we find Dalton, in his new system of "Chemical Philosophy," adopting finally as the natural zero of temperature *minus* 3,000° C.

In Black's lectures we find that he takes a very cautious view with regard to the zero of temperature, but, as usual, is admirably clear with regard to its exposition. Thus he says: "We are ignorant of the lowest possible degree or beginning of heat. Some ingenious attempts have been made to estimate what it may be, but they have not proved satisfactory. Our knowledge of the degrees of heat may be compared to what we should have of a chain, the two ends of which were hidden from us and the middle only exposed to our view. We might put distinct marks on some of the links, and number the rest according as they are nearest to or further removed from the principal links. But, not knowing the distance of any links from the end of the chain, we could not compare them together with respect to their distance or say that one link was twice as far from the end of the chain as another." It is interesting to observe, however, that Black was evidently well acquainted with the work of Amontons, and strongly supports his inference as to the nature of air. Black's own special contribution to low-temperature studies was his explanation of the interaction of mixtures of ice with salts and acids by applying the doctrine of the latent heat of fluidity of ice to account for the frigorific effect. In a similar way Black explained the origin of the cold produced in Cullen's remarkable experiment of the evaporation of ether under the receiver of an air pump by pointing out that the latent heat of vaporization in this case necessitated such a result. Thus, by applying his own discoveries of latent heat, Black gave an intelligent explanation of the cause of all the low-temperature phenomena known in his day.

After the gaseous laws had been definitely formulated by Gay-Lussac and Dalton, the question of the absolute zero of temperature, as deduced from the properties of gases, was revived by Clement and Desormes. These distinguished investigators presented a paper on the subject to the French Academy in 1812, which, it appears, was rejected by that body. The authors subsequently elected to publish it in 1819. Relying on what we know now to have been a faulty hypothesis, they deduced from observations on the heating of air rushing into a vacuum the temperature of *minus* 267 degrees as that of the absolute zero. They further endeavored to show, by extending to lower temperatures the volume or the pressure coefficients of gases given by Gay-Lussac, that at the same temperature of *minus* 267 degrees the gases would contract so as to possess no appreciable volume, or, alternately, if the pressure was under consideration, it would become so small as to be non-existent. Although full reference is given to previous work bearing on the same subject, yet, curiously enough, no mention is made of the name of Amontons. It certainly gave remarkable support to Amontons' notion of the zero to find that simple gases like hydrogen and compound gases like ammonia, hydrochloric, carbonic and sulphurous acids should all point to substantially the same value for this temperature. But the most curious fact about this research of Clement and Desormes is that Gay-Lussac was a bitter opponent of the validity of the inferences they drew either from his work or their own. The mode in which Gay-Lussac regarded the subject may be succinctly put as follows: A quick compression of air to one-fifth volume raises its temperature to 300 degrees, and if this could be made much greater and instantaneous the temperature might rise to 1,000 or 2,000 degrees. Conversely,

if air under five atmospheres were suddenly dilated, it would absorb as much heat as it had evolved during compression, and its temperature would be lowered by 300 degrees. Therefore, if air were taken and compressed to 50 atmospheres or more, the cold produced by its sudden expansion would have no limit. In order to meet this position, Clement and Desormes adopted the following reasoning: They pointed out that it had not been proved that Gay-Lussac was correct in his hypothesis, but that in any case it tacitly involves the assumption that a limited quantity of matter possesses an unlimited supply of heat. If this were the case, then heat would beb unlike any other measurable thing or quality. We know now that Gay-Lussac was wrong in supposing the increment of temperature arising from a given gaseous compression would produce a corresponding decrement from an identical expansion. After this time the zero of temperature was generally recognized as a fixed ideal point, but, in order to show that it was hypothetical, a distinction was drawn between the use of the expressions, zero of absolute temperature and the absolute zero.

The whole question took an entirely new form when Lord Kelvin, in 1848, after the mechanical equivalent of heat had been determined by Joule, drew attention to the great principles underlying Carnot's work on the "Motive Power of Heat," and applied them to an absolute method of temperature measurement, which is completely independent of the properties of any particular substance. The principle was that for a difference of one degree on this scale, between the temperatures of the source and refrigerator, a perfect engine should give the same amount of work in every part of the scale. Taking the same fixed points as for the Centigrade scale, and making 100 of the new degrees cover that range, it was found that the degrees not only within that range, but as far beyond as experimental data supplied the means of comparison, differed by only minute quantities from those of Regnault's air thermometer. The zero of the new scale had to be determined by the consideration that when the refrigerator was at the zero of temperature the perfect engine should give an amount of work equal to the full mechanical equivalent of the heat taken up. This led to a zero of 273 degrees below the temperature of freezing water, substantially the same as that deduced from a study of the gaseous state. It was a great advance to demonstrate by the application of the laws of thermodynamics not only that the zero of temperature is a reality, but that it must be located at 273 degrees below the freezing point of water. As no one has attempted to impugn the solid foundation of theory and experiment on which Lord Kelvin based his thermodynamic scale, the existence of a definite zero of temperaturre must be acknowledged as a fundamental scientific fact.

LIQUEFACTION OF GASES AND CONTINUITY OF STATE.

In these speculations, however, chemists were dealing theoretically with temperatures to which they could not make any but the most distant experimental approach. Cullen, the teacher of Black, had indeed shown how to lower temperature by the evaporation of volatile bodies, such as ether, by the aid of the air pump; and the later experiments of Leslie and Wollaston extended the same principle. Davy and Faraday made the most of the means at command in liquefying the more condensable gases, while at the same time Davy pointed out that they in turn might be utilized to procure greater cold by their rapid reconversion into the aeriform state. Still, the chemist was sorely hampered by the want of some powerful and accessible agent for the production of temperatures much lower than had ever been attained. That want was supplied by Thilorier, who in 1835 produced liquid carbonic acid in large quantities, and further made the fortunate discovery that the liquid could be frozen into a snow by its own evaporation. Faraday was prompt to take advantage of this new and potent agent. Under exhaustion he lowered its boiling point from *minus* 78° C. to *minus* 110° C., and, by combining this low temperature with pressure, all the gases were liquefied by the year 1844, with the exception of the three elementary gases—hydrogen, nitrogen and oxygen—and three compound gases—carbonic oxide, marsh gas and nitric oxide. Andrews, some twenty-five years after the work of Faraday, attempted to induce change of state in the uncondensed gases by using much higher pressures than Faraday employed. Combining the temperature of a solid carbonic acid bath with pressures of 300 atmospheres, Andrews found that none of these gases exhibited any appearance of liquefaction in such high states of condensation. But, so far as change of volume by high compression went, Andrews confirmed the earlier work of Natterer by showing that the gases become proportionately less compressible with growing pressure. While such investigations were proceeding, Regnault and Magnus had completed their refined investigations on the laws of Boyle and Gay-Loussac. A very important series of experiments were made by Joule and Kelvin "On the Thermal Effects of Fluids in Motion," about 1862, in which the thermometrical effects of passing gases under compression through porous plugs furnished important data for the study of the mutual action of the gas molecules. No one, however, had attempted to make a complete study of a liquefiable gas throughout wide ranges of temperature. This was accomplished by Andrews in 1869, and his Bakerian lecture "On the Continuity of the Gaseous and Liquid States of Matter" will always be regarded as an epoch-making investigation. During the course of this research Andrews observed that liquid carbonic acid raised to a temperature of 31° C. lost the sharp concave surface of demarcation between the liquid and the gas, the space being now occupied by a homogeneous fluid, which exhibited, when the pressure was suddenly diminished or the temperature slightly lowered, a peculiar appearance of moving or flickering striæ, due to great local alterations of density. At temperatures above 31° C. the separation into two distinct kinds of matter could not be effected, even when the pressure reached 400 atmospheres. This limiting temperature of the change of state from gas to liquid Andrews called the critical temperature. He showed that this temperature is constant, and differs with each substance, and that it is always associated with a definite pressure peculiar to each body. Thus the two constants, critical temperature and pressure, which have been of the greatest importance in subsequent investigations, came to be defined, and a complete experimental proof was given that "the gaseous and liquid states are only distinct stages of the same condition of matter and are capable of passing into one another by a process of continuous change."

In 1873 an essay "On the Continuity of the Gaseous and Liquid State," full of new and suggestive ideas, was published by van der Waals, who, recognizing the value of Clausius' new conception of the virial in dynamics, for a long-continued series of motions, either oscillatory or changing exceedingly slow with time, applied it to the consideration of the molecular movements of the particles of the gaseous substance and, after much refined investigation and the fullest experimental calculation available at the time, devised his well-known equation of continuity. Its paramount merit is that it is based entirely on a mechanical foundation, and is in no sense empiric; we may therefore look upon it as having a secure foundation in fact, but also as being capable of extension and improvement. James Thomson, realizing that the straight-line breach of continuous curvature in the Andrews isothermals was untenable to the physical mind, propounded his emendation of the Andrews curves, namely, that they were continuous and of S form. We also owe to James Thomson the conception and execution of a three-dimensional model of Andrews' results, which has been of the greatest service in exhibiting the three variables by means of a specific surface, afterwards greatly extended and developed by Prof. Willard Gibbs. The suggestive work of James Thomson undoubtedly was a valuable aid to van der Waals, for, as soon as he reached the point where his equation had to show the continuity of the two states,

this was the first difficulty he had to encounter, and he succeeded in giving the explanation. He also gave a satisfactory reason for the existence of a minimum value of the product of volume and pressure in the Regnault isothermals. His isothermals, with James Thomson's completion of them, were now shown to be the results of the laws of dynamics. Andrews applied the new equation to the consideration of the coefficients of expansion with temperature and of pressure with temperature, showing that although they were nearly equal, nevertheless they were almost independent quantities. His investigation of the capillarity constant was masterly, and he added further to our knowledge of the magnitudes of the molecules of gases and of their mean free paths. Following up the experiments of Joule and Kelvin, he showed how their cooling coefficients could be deduced, and proved that they vanished at a temperature in each case, which is a constant multiple of the specific critical temperature. The equation of continuity developed by van der Waals involved the use of three constants instead of one, as in the old law of Boyle and Charles, the latter being only utilized to express the relation of temperature, pressure and volume, when the gas is far removed from its point of liquefaction. Of the two new constants, one represents the molecular pressure arising from the attraction between the molecules, the other four times the volume of the molecules. Given these constants of a gas, van der Waals showed that his equation not only fitted into the general characters of the isothermals, but also gave the values of the critical temperature, the critical pressure and the critical volume. In the case of carbonic acid, the theoretical results were found to be in remarkable agreement with the experimental values of Andrews. This gave chemists the means of ascertaining the critical constants, provided sufficiently accurate data derived from the study of a few properly-distributed isothermals of the gaseous substance were available. Such important data came into the possession of chemists when Amagat published his valuable paper on "The Isothermals of Hydrogen, Nitrogen, Oxygen, Ethylene," etc., in the year 1880. It now became possible to calculate the critical data with comparative accuracy for the so-called permanent gases oxygen and nitrogen, and this was done by Sarrau in 1882. In the meantime a great impulse had been given to a further attack upon the so-called permanent gases by the suggestive experiments made by Pictet and Cailletet. The static liquefaction of oxygen was effected by Wroblewski in 1883, and thereby the theoretical conclusions derived from van der Waals' equation were substantially confirmed. The liquefaction of oxygen and air was achieved through the use of liquid ethylene as a cooling agent, which enabled a temperature of *minus* 140 degrees to be maintained by its steady evaporation *in vacuo*. From this time liquid oxygen and air came to be regarded as the potential cooling agents for future research, commanding as they did a temperature of 200 degrees below melting ice. The theoretical side of the question received at the hands of van der Waals a second contribution, which was even more important than his original essay, and that was his novel and ingenious development of what he calls "The Theory of Corresponding States." He defined the corresponding states of two substances as those in which the ratios of the temperature, pressure and volume to the critical temperature, pressure and volume respectively were the same for the two substances, and in corresponding states he showed that the three pairs of ratios all coincided. From this a series of remarkable propositions were developed, some new, some proving previous laws that were hitherto only empiric and some completing and correcting faulty, though approximate, laws. As examples, he succeeded in calculating the boiling point of carbonic acid from observations on ether vapor, proved Kopp's law of molecular volumes and showed that at corresponding temperatures the molecular latent heats of vaporization are proportional to the absolute critical temperature, and that under the same conditions the coefficients of liquid expansion are inversely proportional to the absolute critical temperature and that the coefficients of liquid compressibility are inversely proportional to the critical pressure. All these propositions and deductions are in the main correct, though further experimental investigation has shown minor discrepancies requiring explanation. Various proposals have been made to supplement van der Waals' equation so as to bring it into line with experiments, some being entirely empiric, others theoretical. Clausius, Sarrau, Wroblewski, Batteli and others attacked the question empirically, and in the main preserved the co-volume (depending on the total volume of the molecules) unaltered while trying to modify the constant of molecular attraction. Their success depended entirely on the fact that, instead of limiting the number of constants to three, some of them have increased them to as many as ten. On the other hand, a series of very remarkable theoretical investigations have been made by van der Waals himself, by Kammerlingh Onnes, Korteweg, Jaeger, Boltzmann, Dieterici and Rienganum and others, all directed in the main towards an admitted variation in the value of the co-volume, while preserving the molecular attraction constant. The theoretical deductions of Tait lead to the conclusion that a substance below its critical point ought to have two different equations of the van der Waals type, one referring to the liquid and the other to the gaseous phase. One important fact was soon elicited, namely, that the law of correspondence demanded only that the equation should contain not more than three constants for each body. The simplest extension is that made by Reinganum, in which he increased the pressure for a given mean kinetic energy of the particles inversely in the ratio of the diminution of free volume, due to the molecules possessing linear extension. Berthelot has shown how a "reduced" isothermal may be got by taking two other prominent points as units of measurement instead of the critical co-ordinates. The most suggestive advance in the improvement of the van der Waals equation has been made by a lady, Mme. Christine Meyer. The idea at the base of this new development may be understood from the following general statement: van der Waals brings the van der Waals surfaces for all substances into coincidence at the point where volume, pressure and temperature are nothing, and then stretches or compresses all the surfaces parallel to the three axes of volume, pressure and temperature until their critical points coincide. But on this plan the surfaces do not quite coincide, because the points where the three variables are respectively nothing are not corresponding points. Mme. Meyer's plan is to bring all the critical points first into coincidence, and then to compress or extend all the representative surfaces parallel to the three axes of volume, pressure and temperature until the surfaces coincide. In this way, taking 29 different substances, she completely verifies from experiment van der Waals' law of correspondence. The theory of van der Waals has been one of the greatest importance in directing experimental investigation and in attacking the difficult problems of the liquefaction of the most permanent gases. One of its greatest triumphs has been the proof that the critical constants and the boiling point of hydrogen theoretically deduced by Wroblewski from a study of the isothermals of the gas taken far above the temperature of liquefaction are remarkably near the experimental values. We may safely infer, therefore, that if hereafter a gas be discovered in small quantity, even four times more volatile than liquid hydrogen, yet by a study of its isothermals at low temperature we shall succeed in finding its most important liquid constants, although the isolation of the real liquid may for the time be impossible. It is perhaps not too much to say that as a prolific source of knowledge in the department dealing with the continuity of state in matter it would be necessary to go back to Carnot's cycle to find a proposition of greater importance than the theory of van der Waals and his development of the law of corresponding states.

It will be apparent from what has just been said that, thanks to the labors of Andrews, van der Waals and others, theory

had again far outrun experiment. We could calculate the constants and predict some of the simple physical characteristics of liquid oxygen, hydrogen or nitrogen with a high degree of confidence long before any one of the three had been obtained in the static liquid condition permitting of the experimental verification of the theory. This was the more tantalizing, because, with whatever confidence the chemist may anticipate the substantial corroboration of his theory, he also anticipates, with almost equal conviction, that as he approaches more and more nearly to the zero of absolute temperature he will encounter phenomena compelling modification, revision and refinement of formulas which fairly covered the facts previously known. Just as nearly seventy years ago chemists were waiting for some means of getting a temperature of 100 degrees below melting ice, so ten years ago they were casting about for the means of going 100 degrees lower still. The difficulty, it need hardly be said, increases in a geometrical rather than in an arithmetical ratio. Its magnitude may be estimated from the fact that to produce liquid air in the atmosphere of an ordinary laboratory is a feat analogous to the production of liquid water starting from steam at a white heat and working with all the implements and surroundings at the same high temperature. The problem was not so much how to produce intense cold, as how to save it when produced from being immediately leveled up by the relatively superheated surroundings. Ordinary non-conducting packings were inadmissible, because they are both cumbrous and opaque, while in working near the limits of our resources it is essential that the product should be visible and readily handled. It was while puzzling over this mechanical and manipulative difficulty in 1892 that it occurred to me that the principle of an arrangement used nearly twenty years before in some calorimetric experiments, which was based upon the work of Dulong and Petit on radiation, might be employed with advantage, as well as to protect cold substances from heat as hot ones from rapid cooling. I therefore tried the effect of keeping liquefied gases in vessels having a double wall, the annular space between being very highly exhausted. Experiments showed that liquid air evaporated at only one-fifth of the rate prevailing when it was placed in a similar unexhausted vessel, owing to the convective transference of heat by the gas particles being enormously reduced by the high vacuum. But, in addition, these vessels lend themselves to an arrangement by which radiant heat can also be cut off. It was found that when the inner walls were coated with a bright deposit of silver the influx of heat was diminished to one-sixth the amount entering without the metallic coating. The total effect of the high vacuum and the silvering is to reduce the ingoing heat to about 3 per cent. The efficiency of such vessels depends upon getting as high a vacuum as possible, and cold is one of the best means of effecting the desired exhaustion. All that is necessary is to fill completely the space that has to be exhausted with an easily-condensable vapor, and then to freeze it out in a receptacle attached to the primary vessel that can be sealed off. The advantage of this method is that no air pump is required, and that theoretically there is no limit to the degree of exhaustion that can be obtained. The action is rapid, provided liquid air is the cooling agent, and vapors like mercury, water or benzol are employed. It is obvious that when we have to deal with such an exceptionally volatile liquid as hydrogen the vapor filling may be omitted, because air itself is now an easily-condensable vapor. In other words, liquid hydrogen, collected in such vessels with the annular space full of air, immediately solidifies the air, and thereby surrounds itself with a high vacuum. In the same way, when it shall be possible to collect a liquid boiling on the absolute scale at about 5 degrees, as compared with the 20 degrees of hydrogen, then you might have the annular space filled with the latter gas to begin with, and yet get directly a very high vacuum, owing to the solidification of the hydrogen. Many combinations of vacuum vessels can be arranged, and the lower the temperature at which we have to operate the more useful they become. Vessels of this kind are now in general use, and in them liquid air has crossed the American continent. Of the various forms, that variety is of special importance which has a spiral tube joining the bottom part of the walls, so that any liquid gas may be drawn off from the interior of such a vessel. In the working of regenerative coils such a device becomes all-important, and such special vessels cannot be dispensed with for the liquefaction of hydrogen.

In the early experiments of Pictet and Cailletet cooling was produced by the sudden expansion of the highly-compressed gas, preferably at a low temperature, the former using a jet that lasted for some time, the latter an instantaneous adiabatic expansion in a strong glass tube. Neither process was practicable as a mode of producing liquid gases, but both gave valuable indications of partial change into the liquid state by the production of a temporary mist. Linde, however, saw that the continuous use of a jet of highly-compressed gas, combined with regenerative cooling, must lead to liquefaction on account of what is called the Kelvin-Joule effect; and he succeeded in making a machine, based on this principle, capable of producing liquid air for industrial purposes. These experiments had proved that, owing to molecular attraction, compressed gases passing through a porous plug or small aperture were lowered in temperature by an amount depending on the difference of pressure, and inversely as the square of the absolute temperature. This means that for a steady difference of pressure the cooling is greater the lower the temperature. The only gas that did not show cooling under such conditions was hydrogen. Instead of being cooled, it became actually hotter. The reason for this apparent anomaly in the Kelvin-Joule effect is that every gas has a thermometric point of inversion above which it is heated, and below which it is cooled. This inversion point, according to van der Waals, is six and three-quarter times the critical point. The efficiency of the Linde process depends on working with highly-compressed gas well below the inversion temperature, and in this respect this point may be said to take the place of the critical one, when in the ordinary way direct liquefaction is being effected by the use of specific liquid cooling agents. The success of both processes depends upon working with a certain temperature range, only the Linde method gives us a much wider range of temperature within which liquefaction can be effected. This is not the case if, instead of depending on getting cooling by the internal work done by the attraction of the gas molecules, we force the compressed gas to do external work, as in the well-known air machines of Kirk and Coleman. Both these inventors have pointed out that there is no limit of temperature, short of liquefaction of the gas in use in the circuit, that such machines are not capable of giving. While it is theoretically clear that such machines ought to be capable of maintaining the lowest temperatures, and that with the least expenditure of power, it is a very different matter to overcome the practical difficulties of working such machines under the conditions. Coleman kept a machine delivering air at *minus* 83 degrees for hours, but he did not carry his experiments any further. Recently Monsieur Claude, of Paris, has, however, succeeded in working a machine of this type so efficiently that he has managed to produce one liter of liquid air per horse-power expended per hour in the running of the engine. This output is twice as good as that given by the Linde machine, and there is no reason to doubt that the yield will be still further improved. It is clear, therefore, that in the immediate future the production of liquid air and hydrogen will be effected most economically by the use of machines producing cold by the expenditure of mechanical work.

LIQUID HYDROGEN AND HELIUM.

To the physicist the copious production of liquid air by the methods described was of peculiar interest and value as affording the means of attacking the far more difficult problem of the liquefaction of hydrogen, and even as encouraging the hope that liquid hydrogen might in time be employed for the liquefaction of yet more volatile elements, apart from the importance

which its liquefaction must hold in the process of the steady advance towards the absolute zero. Hydrogen is an element of especial interest, because the study of its properties and chemical relations led great chemists like Faraday, Dumas, Daniell, Graham and Andrews to entertain the view that if it could ever be brought into the state of liquid or solid it would reveal metallic characters. Looking to the special chemical relations of the combined hydrogen in water, alkaline oxides, acids and salts, together with the behavior of these substances on electrolysis, we are forced to conclude that hydrogen behaves as the analogue of a metal. After the beautiful discovery of Graham that palladium can absorb some hundreds of times its own volume of hydrogen, and still retain its luster and general metallic character, the impression that hydrogen was probably a member of the metallic group became very general. The only chemist who adopted another view was my distinguished predecessor, Professor Odling. In his "Manual of Chemistry," published in 1861, he pointed out that hydrogen has chlorous as well as basic relations, and that they are as decided, important and frequent as its other relations. From such considerations he arrived at the conclusion that hydrogen is essentially a neutral or intermediate body, and therefore we should not expect to find liquid or solid hydrogen possess the appearance of a metal. This extraordinary prevision, so characteristic of Odling, was proved to be correct some thirty-seven years after it was made. Another curious anticipation was made by Dumas in a letter addressed to Pictet, in which he says that the metal most analogous to hydrogen is magnesium, and that probably both elements have the same atomic volume, so that the density of hydrogen, for this reason, would be about the value elicited by subsequent experiments. Later on, in 1872, when Newlands began to arrange the elements in periodic groups, he regarded hydrogen as the lowest member of the chlorine family; but Mendeleef, in his later classification, placed hydrogen in the group of the alkaline metals. On the other hand, Dr. Johnstone Stoney classes hydrogen with the alkaline earth metals and magnesium. From this speculative divergency it is clear no definite conclusion could be reached regarding the physical properties of liquid or solid hydrogen, and the only way to arrive at the truth was to prosecute low-temperature research until success attended the efforts to produce its liquefaction. This result I definitely obtained in 1898. The case of liquid hydrogen is, in fact, an excellent illustration of the truth already referred to, that no theoretical forecast, however apparently justified by analogy, can be finally accepted as true until confirmed by actual experiment. Liquid hydrogen is a colorless, transparent body of extraordinary intrinsic interest. It has a clearly-defined surface; is easily seen; drops well, in spite of the fact that its surface tension is only the thirty-fifth part of that of water, or about one-fifth that of liquid air, and can be poured easily from vessel to vessel. The liquid does not conduct electricity, and, if anything, is slightly diamagnetic. Compared with an equal volume of liquid air, it requires only one-fifth the quantity of heat for vaporization. On the other hand, its specific heat is ten times that of liquid air or five times that of water. The coefficient of expansion of the fluid is remarkable, being about ten times that of gas. It is by far the lightest liquid known to exist, its density being only one-fourteenth that of water. The lightest liquid previously known was liquid marsh gas, which is six times heavier. The only solid which has so small density as to float upon its surface is a piece of pith wood. It is by far the coldest liquid known. At ordinary atmospheric pressure it boils at *minus* 252.5 degrees or 20.5 degrees absolute. The critical point of the liquid is about 29 degrees absolute, and the critical pressure not more than 15 atmospheres. The vapor of the hydrogen arising from the liquid has nearly the density of air; that is, it is 14 times that of the gas at the ordinary temperature. Reduction of the pressure by an air pump brings down the temperature to *minus* 258 degrees, when the liquid becomes a solid resembling frozen foam; and this, by further exhaustion, is cooled to *minus* 260 degrees, or 13 degrees absolute, which is the lowest steady temperature that has been reached. The solid may also be got in the form of a clear, transparent ice, melting at about 15 degrees absolute, under a pressure of 55 mm., possessing the unique density of one-eleventh that of water. Such cold involves the solidification of every gaseous substance but one that is at present definitely known to the chemist, and so liquid hydrogen introduces the investigator to a world of solid bodies. The contrast between this refrigerating substance and liquid air is most remarkable. On the removal of the loose plug of cotton wool used to cover the mouth of the vacuum vessel in which it is stored, the action is followed by a miniature snow storm of solid air, formed by the freezing of the atmosphere at the point where it comes into contact with the cold vapor rising from the liquid. This solid air falls into the vessel and accumulates as a white snow at the bottom of the liquid hydrogen. When the outside of an ordinary test tube is cooled by immersion in the liquid, it is soon observed to fill up with solid air; and if the tube be now lifted out a double effect is visible, for liquid air is produced both in the inside and on the outside of the tube—in the one case by the melting of the solid, and in the other by condensation from the atmosphere. A tuft of cotton wool soaked in the liquid and then held near the pole of a strong magnet is attracted, and it might be inferred therefrom that liquid hydrogen is a magnetic body. This, however, is not the case; the attraction is due neither to the cotton-wool nor to the hydrogen—which, indeed, evaporates almost as soon as the tuft is taken out of the liquid—but to the oxygen of the air, which is well known to be a magnetic body, frozen in the wool by the extreme cold.

[*To be concluded.*]

PROF. ROWLAND'S PAPERS.

"SCIENCE" states that the volume containing the physical papers of the late Prof. Henry A. Rowland is now nearly ready for distribution to its subscribers. It has been edited under the direction of a committee consisting of President Remsen, Professor Welch and Professor Ames. In the book, which contains about 750 pages, are collected not alone Professor Rowland's strictly scientific papers and his public addresses, but also a detailed description of his ruling engine, with plates and photographs. The memorial address of Professor Mendenhall serves as a biographical sketch, which is accompanied by a portrait of Professor Rowland. The subjects treated in these papers cover a wide range. In heat there is the great memoir on the mechanical equivalent of heat, with several shorter articles on thermometers. In electricity and magnetism there are the fundamental researches on magnetization, on the magnetic effort of electrical connection, on the value of the ohm, on the theory and use of alternating currents, etc. In light there are the renowned discovery and theory of the concave grating and the long series of investigations made in the field of spectroscopy.

OBITUARY.

JOHN HALL GLADSTONE, D.Sc., Ph.D., F.R.S., died, on October 6th, in London. His name is best known in electrochemical circles, from the fact that some fifteen years ago he worked out, in conjunction with Dr. Tribe, the so-called double sulphate theory of the lead storage battery. This theory has since been repeatedly tested, and is now generally accepted, especially since Dolezalek's elaborate recent researches. Dr. Gladstone reached an age of seventy-five years.

THE INSTITUTION OF ELECTRICAL ENGINEERS OF GREAT BRITAIN has accepted the invitation of the American Institute of Electrical Engineers to hold a joint meeting in 1904 in the United States.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

BY GEORGE P. SCHOLL.

ELECTRIC FURNACES AND FURNACE PRODUCTS.

Process of Manufacturing Calcium Carbide. Isaiah L. Roberts, New York. Patent No. 708,921, September 9, 1902. Application filed March 18, 1897.

The process consists essentially in the substitution of finely-ground anthracite coal for coke in the mixture of raw materials for the carbide furnace. Coke, as a component of the mixture, is said to be objectionable for various reasons—principally because, on account of its low specific gravity, it tends to float on top of the melted carbide, and is therefore only partially converted into carbide. As a consequence, a kind of segregation manifests itself in the block of carbide produced, which will show itself in the variations of chemical composition. A further disadvantage is stated to be that finely-ground coke gives rise to clouds of dust, and on that account is extremely objectionable to the workmen. Anthracite coal is of a higher specific gravity than coke, and, moreover, it does not have that dust-forming tendency of coke. The carbide thus produced is said not to burn so readily upon its surface when it is removed from the furnace as the product obtained from coke, and an increased yield is also claimed. The proportion may be the same as ordinarily employed, but a somewhat less proportion of anthracite also works satisfactorily. As far as anthracite coal is concerned as a raw material in the manufacture of calcium carbide, it does not seem to be used in this country. In the practice of the Union Carbide Co., Niagara Falls, N. Y. (Richards, "Electrochemical Industries," 1902, p. 22), ground coke is used in connection with burnt lime, and this company control almost all the carbide production in America. In Europe, however, and especially in France, anthracite is already used in the manufacture of calcium carbide, as appears from a paper read by Gall, on the "Industry of Calcium Carbide in France," before the Fourth International Congress of Applied Chemistry, at Paris, 1900. He says: "Charcoal, coke and anthracite have been used industrially. . . . The manufacturers of calcium carbide have preferred to avail themselves of the anthracite, which England continues to furnish of excellent quality. The anthracites of the Alps are, unfortunately, too impure. It is, however, interesting to note the ingenious solution of the problem found by the Compagnie de Fives-Lille. The anthracites of Bosel (Tarentaire), where the works are situated, leave an ash consisting almost entirely of silica, and a method is used by the company which permits them to obtain a product of the highest interest for metallurgy, together with the carbide, namely, ferro silicon, remarkable specimens of which were exhibited at the exposition." As the application for the patent was made in March, 1897, it has taken more than five years to get it through the Patent Office. An industry like that of calcium carbide, which has made such rapid strides in the course of comparatively few years, could hardly be expected to wait that long for the suggestion of improvements.

Carborundum Articles, and Process of Making Same. Frank J. Tone, Niagara Falls, N. Y. Patent No. 709,808, September 23, 1902. Application filed January 2, 1901.

This patent is assigned to the Carborundum Co., of which the inventor is superintendent. It contains the description of a process for the utilization of the so-called amorphous carborundum, a by-product of the carborundum furnace, which is found in the carborundum furnace at the end of the operation, surrounding the core of crystalline carborundum, in a zone where the heat has not been sufficient to change it into the crystalline variety. It was customary to carefully separate it from the crystalline product and mix it with another charge of raw material. This amorphous carborundum is now, according to the patent, pressed into bricks, or other desired shapes, and subjected again to the action of the current, when it is changed into a crystalline mass of carborundum. It is claimed that in this way the bricks or other shapes, though very firm and coherent, are obtained in a considerably more porous condition than if they were molded directly out of crystalline carborundum, and are consequently more desirable for many purposes, as lining furnaces, fire boxes, etc., where they have to withstand sudden changes of temperature without cracking or disintegration. For purposes where still more porous articles are wanted, the inventor proposes to mold them from a mixture of carbon and silica in the proper proportions, and then subject them to the heat of the electric furnace, in order to convert them into carborundum, which product then is said to be more coherent and dense than the ordinary carborundum furnace product, but more porous and of less weight per volume than if it were made of compressed amorphous carborundum. For a porosity between these two grades, amorphous carborundum and a mixture of carbon and silica, as described, are mixed together in the desired proportions. It is also proposed to make such articles of carbide of boron, by molding them either directly from the amorphous material obtained in the manufacture of that carbide or from a mixture of carbon and boracic acid, and treating them in the same manner as described above. Whenever it is desired, a solution of a binding material, such as silicate of soda, glue, etc., may also be added to the mixture before compressing it, which material will be volatilized in the subsequent furnace operation. These bricks will no doubt be a valuable and welcome addition to the list of refractory materials at the disposal of the metallurgist.

Apparatus and Processes for the Electrolytic Production of Metals and Compounds. Bleaching Apparatus. Chauncey Cook Clark, Philadelphia, Pa. Patent No. 708,796, September 9, 1902. Application filed January 22, 1901.

The object of this invention is stated to be "an apparatus for the manufacture of bleaching material in an inclosed receptacle by electrolysis, to thereby prevent the escape of the valuable chlorine gas separated from the chloride of sodium, and assure its absorption by the inclosed liquid." The apparatus in which the electrolysis is carried out is, in appearance, almost identical with the one described by the same inventor in patent No. 706,529, of August 12, 1902, under the head of "Electrochemical Apparatus," noted on page 65, Vol. I, of this journal. The application for the present apparatus was filed on January 22, 1901, while the application for the one described in patent No. 706,529 was filed on September 20, 1901. As a consequence, the apparatus under consideration, the result of an earlier application, does not contain improvements in the mechanical construction which were embodied in the later application. All the objections which were raised to that apparatus, on page 63, Vol. I, of this journal, are applicable here. One statement is of interest, as showing how easy the problem of producing bleaching solutions is solved on paper. It is stated: "The separation being produced by a series of electrodes suspended in the salt solution, the residium comprising the impurities of the solution, as the earthy, saline, vegetable (!), animal (!), metallic matter, etc., falling to the bottom of the receptacle, where means are provided for its removal." It is a pity that the impurities cannot be so easily disposed of in the actual electrochemical practice in general, and the manufacture of bleaching solutions in particular. Instead of that, they seem to be most obstinately bent upon taking part in the decomposition and producing many undesired

and annoying complications, so that in most instances a preparatory chemical treatment of the electrolytes has to be resorted to in order to remove them.

Electrolytically Treating Ores. Clinton Emerson Dolbear, Boston, Mass. Patent No. 709,817, September 23, 1902. Application filed June 3, 1901.

This invention relates to "a new and improved method of producing from raw ores metallic copper or other metals by electrolysis in the wet way." The inventor describes his process as follows: "I take a body of the metal-bearing ore that is soluble in a dissolved nitrate or in nitric acid, crush it and subject it to the action of a nitrate in solution or to nitric acid mixed with sulphuric acid. The object of the nitrate or nitric acid is to furnish the nitric acid radical in quantity sufficient to accomplish the necessary chemical changes. An excess of nitric acid will not interfere with the working of the process. The sulphuric acid will not of itself attack the ore if it be in a state of sulphide or metallic copper, but in the presence of the nitric acid radical it will do so. If a nitrate be used—for instance, Chile niter (sodium nitrate)—the sulphuric acid takes the sodium from the nitrate, liberates the nitric acid radical which in its turn will attack the sulphide, dissolving the base. The sulphuric acid takes the metal from the nitric acid radical, forming the sulphate. During this process the nitric acid loses oxygen, forming nitric oxide, which, under usual conditions, will rise to the surface and be lost." The inventor then proposes to put an insoluble anode, carbon, for example, on the bottom of the electrolytic vat, stating that he can use also anodes of gold or platinum; but it is very probable that he will not use those in practice if he wants anybody to invest in his apparatus. The cathode is of the composition of the metal, to be "plated out" of the bath. The electrolytic operation is described as follows: "When current is flowing, the positive terminal will liberate oxygen, which, passing through the solution, oxydizes the nitric oxide back to nitric acid. This is then in a condition to take up more metal, react with the sulphuric acid and again go through the process just described. The current, of course, at the same time plates the metal onto the cathode, thereby in one operation giving the desired metal from the raw ore." As will be seen, it is proposed to utilize for the solution of the metallic constituents of the ore the well-known reaction used in the laboratory for the production of nitric oxide, which consists in treating copper turnings with a saturated solution of saltpeter, and then introducing concentrated sulphuric acid. The reaction takes place according to the equation:

$$3\,Cu + 2\,NaNO_3 + 4\,H_2SO_4 = 3\,CuSO_4 + Na_2SO_4 + 4\,H_2O + 2\,NO.$$

Theoretically, the reactions described as taking place in the solution and electrolysis are all possible, but, unfortunately, the reagents described will not only dissolve the principal metallic constituent of the ore, but also all the other metals present in it, a fact which the inventor unconsciously admits by claiming his process to be universally applicable to ores. If this is the case, the action of the current will not only result in "plating out" the one metal which the inventor desires to obtain, but will deposit all of them. This will be especially true in this case, as the mass of ore resting on the anodes, between the two electrodes, will of necessity increase the resistance of the solution to the passage of the current, and will prevent the application of the artifice of using a low enough voltage for decomposition f. i. in the case of copper ores, in order to deposit the copper only by keeping the voltage of the bath below the decomposition value of the salts of the other metals present. The problem of purification of the electrolyte, which seems to have been entirely neglected in the process under consideration, is a very serious one (see, for instance, the patent noted below of Tossisza). The use of nitrates as electrolytes is also more or less undesirable in practice, as they are not by any means as easily handled as the sulphates and chlorides. If the nitric acid electrolyte is not regenerated in the process, then it would be eo ipso inapplicable in practice, as the use of such an expensive reagent would be out of the question, a fact which is also emphasized by Schnabel in his "Hand-book of Metallurgy," in speaking about copper sulphide ores, where he says: "The energetic solvents, such as aqua regia, nitric acid, chlorine and hot concentrated sulphuric acid, are too dear to be applicable on a large scale." It would, moreover, seem as though a very fine crushing of the ores was necessary for the successful operation of a process like the one under consideration, a fact which would increase the cost of operation considerably. If this process has been noted in such detail, it has been done with a view of considering it as a representative of its class, bearing in mind that it is not always the theoretically most perfect process which gives the best results in practice.

Electrometallurgic Treatment of Ores of Copper and Other Metals. Constantin Jean Tossisza, Paris, France. Patent No. 710,346, September 30, 1902. Application filed August 6, 1901.

The inventor states that heretofore the direct electrolytic treatment with insoluble anodes of the solutions obtained by the action of sulphuric acid on previously roasted copper ores has been impracticable, because it required, before all, a complete purification of the solution obtained in order to free them from all sulphates other than the sulphate of copper. Such a purification being very difficult, the direct electrolytic treatment was, for that reason, industrially inapplicable. It is intended to overcome that difficulty by making use of the low voltage of decomposition of the copper sulphate. It is, however, very difficult in practice to maintain this low voltage of decomposition, on account of the polarization manifesting itself at the anode, and thus causing a rise of potential above the voltage of decomposition of the other salts present. Consequently the deposit, which was pure in the beginning, will be more and more contaminated with other metals as the electrolysis proceeds. The one thing to do, then, would be to prevent this polarization, and this the inventor proposes to do by introducing a depolarizer, for which he uses sulphurous acid. The anodes are made of carbon, and the sulphurous acid may be introduced either as solution or in the form of gas outside of the anode, or through the anode itself, for which purpose the anode is made hollow. The inventor says that he has ascertained that the transformation of the sulphurous acid into sulphuric acid at the anode gives rise to an electromotive force, which diminishes the necessary voltage and lowers it to two-tenths of a volt. "One can thus obtain a very beautiful deposit of pure electrolytic copper directly from an impure solution with a sufficient intensity at a voltage of about six-tenths of a volt," whereas in all processes heretofore known one could only obtain this electrolysis with insoluble anodes at voltages above 1 3-10 volts. The sulphurous acid which is used is preferably obtained from the preliminary treatment of the sulphite ores, which are roasted to produce oxides and sulphurous acid gas, which is used as such or in solution. The oxides of the metals produced are then dissolved in sulphuric acid and subjected to electrolysis. The idea of using sulphurous acid as a depolarizing agent in the deposition of copper is not new, as may be seen from Borcher's "Electro-Metallurgy," page 214, where it is stated that in Stolberg, Germany, sulphurous acid had been used for the same purpose, and that a patent for the same idea was already applied for in 1885.

Electrolytic Decomposition of Alkaline Salts. Edwin Edser and Meyer Wildermann, London, England. Patent No. 709,971, September 30, 1902. Application filed March 28, 1901.

This specification applies to the electrolysis of alkaline salts in those forms of apparatus in which mercury is used as a means of absorbing the alkali metal. The inventors claim that they are able to affect the decomposition of the alkali amalgam quicker than before by bringing it into contact with pieces of

carbon having part of their surface coated with a suitable electro-deposited metal.

STORAGE BATTERIES.

Electric Accumulator Plate. Alexander Fischer, Berlin, Germany. Patent No. 708,334, September 2, 1902.

This invention relates to improvements in electric accumulator plates, consisting of sheets of lead folded into serpentine form. The objects of the invention are, first, to stiffen the plates, and, secondly, to increase their active surface. In carrying out this invention, the sheets of lead which are to be converted into accumulator plates are bent or corrugated so as to produce a number of relatively deep parallel grooves, running from top to bottom of the plates. At the apex of each corrugation a number of tongues are cut out, thus producing openings for the passage of the electrolyte. Along the top and bottom edge of the plate bars are provided, in order to stiffen the plate laterally. The arrangement thus described constitutes the framework of the plates, which are then ready to be formed and filled with the active mass.

Method of Manufacturing Secondary Battery Plates. George H. Christian, Cleveland, Ohio. Patent No. 708,695, September 9, 1902. Application filed December 7, 1901.

The invention relates to the manufacture of secondary batteries, and is particularly applicable to the preparation of the spongy lead element of such batteries. The formation of the spongy lead from the peroxide is carried out either in an electrolyte composed of a solution of dilute sulphuric acid or plates provided with litharge or red lead are respectively caused to constitute the cathode and anode of an electrolytic cell, with an electrolyte consisting of dilute sulphuric acid. As a result of the electrolysis, the litharge is reduced to spongy lead, and the red lead changed to lead peroxide. Instead of conducting both these operations in an electrolyte composed of dilute sulphuric acid, the inventor substitutes an electrolyte consisting of a solution of an organic acid, such as oxalic or formic acid, or a compound of such acid with an alkaline "earth," such as oxalate of potassium, oxalate of sodium, etc. A solution of about one pound of oxalic acid in one gallon of water is used by preference. On passing the current, of preferably about ½ ampère per square inch of plate surface, the peroxide is rapidly reduced to spongy lead. After the reduction is complete, the spongy lead plates are immersed in a bath of running water, where they are left for about twelve hours, in order to thoroughly remove the carbonic acid and oxalic acid remaining in the pores of the lead. The inventor states that by this means he has found that spongy lead plates having superior physical and electrical qualities, with less loss of active material, are produced, a wider variation in the qualities of the current used being permitted. These plates are also claimed to have a greater electrical capacity per pound of lead than other plates. It will be seen that the inventor proposes rather expensive electrolytes in place of the dilute sulphuric acid used heretofore.

Method of Manufacturing Plates for Secondary Batteries. George H. Christian, Cleveland, Ohio. Patent No. 708,694, September 9, 1902. Application filed December 7, 1901.

This specification is almost identical in phraseology with the preceding one by the same inventor. The only change is in the composition of the electrolyte, where, instead of a solution of oxalic acid and water, there is now substituted a solution of a compound of an organic acid with an alkaline "earth," such as oxalate of potassium, oxalate of sodium, etc., which oxalate is preferably prepared in solution with water. The same improvements as claimed above for oxalic acid alone are, of course, claimed in this specification for potassium and sodium oxalate. The first claim reads: "In the process of manufacturing plates for secondary batteries, the step which consists in electrolytically reducing an oxide of lead in an electrolytic cell having an electrolyte containing a compound of an organic reducing agent." This claim is certainly broad enough to satisfy any inventor.

Jar for Storage Batteries. Patrick Kennedy, Brooklyn, N. Y. Patent No. 709,157, September 16, 1902. Application filed January 6, 1902.

This application describes an improved form of receptacle or jar for the plates of storage batteries, which is especially applicable when the storage batteries are used in installations for the lighting of railway cars. The inventor provides a lining of soft vulcanized rubber, closely fitted into an outer receptacle, ordinarily made of wood. He also provides suitable protecting guards or buffers on the sides, which serve to keep the battery plates from contact with the lining. A ribbed plate of any suitable ceramic material is resting on the rubber lining on the bottom. It is claimed that this jar will withstand the jolting or shocks to which it may be subjected on the cars without rupture or cracking of the lining.

Secondary Battery. William L. Silvey, Dayton, Ohio. Patent No. 709,611, September 23, 1902. Application filed February 8, 1902.

This invention relates to the details whereby storage batteries may be more perfectly arranged, easier assembled and taken apart for repairs than has heretofore been possible. Any battery man of ordinary intelligence should be able to make his own repairs, and with but little necessary apparatus. It is proposed to accomplish this by doing away with the connecting bar welded to the battery plates and substitute therefor a slotted bar, to which the various plates are fastened by screw bolts. Various mechanical arrangements of the connecting bar are described at length. The greatest objection to an arrangement of this kind seems to lie in the multiplication of individual contact points, each of which is liable to get out of order, and will necessitate a great deal more watching than is necessary when the plates are welded to the connecting bar.

Electric Separator for Batteries. Arthur W. Harrison, Los Angeles, Cal. Patent No. 708,708, September 9, 1902. Application filed May 7, 1902.

The patent aims at providing an efficient separating medium for storage-battery plates, especially in batteries designed for use in automobiles, where it is desirable that the battery should be as light as possible, and that the electrodes should be kept perfectly insulated from each other. Corrugated sheet rubber or corrugated sheets of wood are both unsatisfactory. It is claimed that a plate separator made from yucca wood will furnish a very tough and light non-conducting separator, which permits a free circulation of the electrolyte and yet keeps the electrodes perfectly insulated from each other. The material, after being cut from the tree in the desired length and thickness, is treated by boiling it in a weak solution of sulphuric acid or caustic soda until the starch and other non-fibrous material is dissolved. It is then dried and ready for use. If the non-fibrous material is not removed, it is said to clog the circulation and interfere with the action of the battery.

Electric Battery. Timke Henry Klinker, Jr., and Richard Gabrielsky, Jersey City, N. J. Patent No. 710,278, September 30, 1902.

The cell described in this specification is one of the class of dry batteries. The positive electrode is formed of a sheet of zinc, constructed in such a way as to present as large a surface as possible. The negative electrode is composed of carbon, corrugated at its lower part, also in order to increase its surface. The cell is filled with sal ammoniac, which is used either alone or in combination with some other well-known material. Provision is also made for moistening the filling and thus "reactivating" the cell, by arranging conduits for that purpose in the carbon and zinc electrodes. The whole is inclosed in a casing of sheet lead, formed from one piece of material, without a seam.

MISCELLANEOUS.

Process of Manufacturing Nitrogen Compounds from Atmospheric Nitrogen. Charles T. Bradley and Dimmitt Ross Lovejoy, New York. Patent No. 709,867, September 30, 1902. Application filed March 19, 1900.

This patent describes the process for the manufacture of nitrogen compounds from atmospheric air evolved by Mr. Charles T. Bradley, the president, and Mr. D. R. Lovejoy, the electrician of the Atmospheric Products Co., Niagara Falls, N. Y., the works of which were described and illustrated in an article by Prof. J. W. Richards in this journal, Vol. I, pages 21 to 23. The process has proven so successful on an experimental scale that a large plant is to be built at Niagara Falls, part of which is already in process of erection. The inventors have found that the silent electric discharge is not capable of effecting nitrification to an appreciable amount, and that the ordinary spark is also of comparatively little value. In order to produce a large yield, an arc is absolutely necessary, and the best results are obtained by using a spark as thin as possible. The patent covers the process for the nitrification of air, describing also briefly the apparatus in which the nitrification is carried out. The various steps of the process are illustrated by a plan of the complete installation, as shown by Fig. 1. The atmospheric air enters into the systems of apparatus by the air inlet 58. The air entering the nitrification apparatus should be as dry as possible, in order to reduce the formation of any nitric acid in the apparatus itself to a minimum. This is said to be of advantage when the nitrous oxide and nitrogen

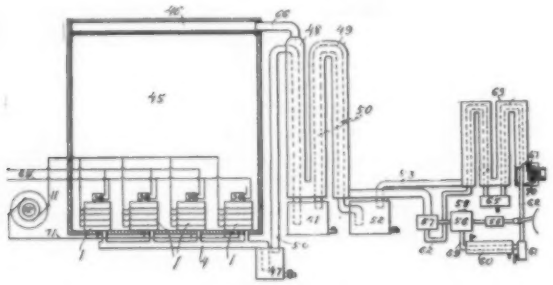


FIG. 1—FIXATION OF NITROGEN FROM THE AIR.

tetroxide are to be collected as such, and it further prevents the corrosion of the metallic parts of the nitrification apparatus. In order to obtain this, the air, after entering the system, is passed through a series of cooling and expansion apparatus. From the intake 58 it passes into a compressor 56, worked by an engine 55, whence it passes into pipe 59, cooled by water cooler 60. A trap, 61, here allows the moisture removed thus far to drain off, while the air passes on through pipe 62 into another cooler 63, where more moisture is removed by trap 65. It next enters the expansion engine 57, where it is still further cooled; and from there passes successively into two apparatuses, 49 and 48, which serve as coolers for the nitrogen compounds coming from the nitrification apparatus, and where the cooled air acts as a cooling medium in order to condense the nitrogen tetroxide and trioxide. From receiver 48 the cold, dry air passes through pipe 66 into the distributing chamber 46, arranged at the top of chamber 45, whence it enters the nitrification apparatus 36. After nitrification, it passes out by conduit 4, depositing any nitric acid which may have been formed in trap 47, and then enters successively the coolers 48 and 49. In the first one of these it is cooled to about 0° C., in order to condense substantially all the nitrogen tetroxide, which collects in the receiving vessel 51. The second apparatus is cooled still further in order to condense all the nitrogen trioxide which collects in receiver 52. From receiver 52 the gases pass through pipe 53 into cooler 63, where they again act as cooling mediums, and are finally discharged from opening 67 by blower 70, assisting, if necessary, in the circulation. It is stated that in this process the amount of nitrous products is only about 2 to 3 per cent. of the amount of air supplied, by which means the waste due to dissociation by the action of the arcs on the combination products already formed is said to be substantially prevented. The nitrous products are obtained as such, *i. e.*, as anhydrous oxides of nitrogen. In collecting the products by the use of sulphuric acid, the gases are drawn in an upward direction through a tower filled with obstructing material, over which the sulphuric acid introduced at the top of the tower trickles down. The acid absorbs substantially all the

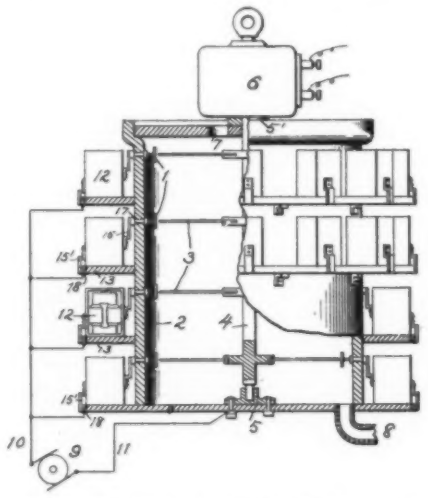


FIG. 2—FIXATION OF NITROGEN FROM THE AIR.

nitrous products, and passes then into a heated receptacle, where the expulsion of the nitrous products as vapor takes place, such vapor passing through a condensing apparatus into a suitable receptacle.

Apparatus for Subjecting Gases to High-Tension Discharges. Charles S. Bradley, New York, and D. R. Lovejoy, Niagara Falls, N. Y. Patent No. 709,869, September 30, 1902. Application filed March 9, 1900.

This specification describes the apparatus used in the process described above. Figs. 2 and 3 supplement Fig. 19 in Professor

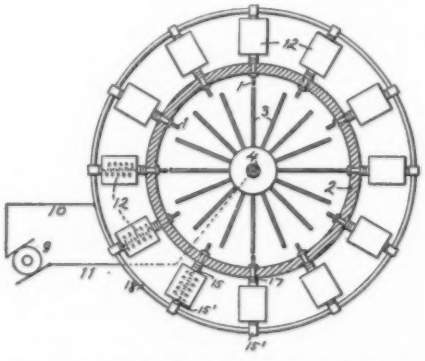


FIG. 3—FIXATION OF NITROGEN FROM THE AIR.

Richards' article, on page 21 of Vol I of this journal, and present a partly sectional elevation and a horizontal section of the apparatus. Fig. 4 represents a movable shaft, having a series of terminals 3, and connected to one pole of the dynamo 9, by means of wire 11 and bearing 5. Immediately opposite the terminals 3 are arranged opposing terminals 1, connected in parallel to the other pole of the dynamo by means of wire 10, and having included in the connection an inductance or self-induction device 12, represented as consisting of coils of wire connected in series and wound on a core of magnetic material.

To facilitate the connecting of these induction coils, they are arranged on annular shelves 13, and bear on one side by their terminal 15, against a strip 17, which is connected to terminal 1, and on the other side by their terminal 15 against a contact ring 18, connected in parallel with the other contact rings by wire 10 to dynamo 9, as noted above; 6 is the motor which revolves the shaft 4; the air enters the apparatus at opening 7, and is drawn off through opening 8. The operation of the apparatus, supplemented by a number of practical details and illustrations, is fully described by Prof. Joseph W. Richards in this journal, Vol. I, pages 11 to 23. The inventors state that the apparatus, though adapted to carry out the process of nitrification of air by exposing a current of air to the action of intermittently elongated and interrupted arcs, may also be applied to the treatment of other gases or mixtures of gases with electric discharges.

Rotary Apparatus for the Production of Diffused Electric Discharges. Mauris Otto, Neuilly, France. Patent No. 707,797, August 26, 1902. Application filed November 12, 1901.

This invention relates to an improved rotating machine for effecting a continuous and uniform discharge of electricity across a space through which a quantity of gas may be caused to pass in order that it may be subjected to electrical treatment. The construction of the apparatus, which is specially designed for the formation of ozone by silent discharge, is shown by Fig. 4. It consists essentially of a metallic plate *h*, which

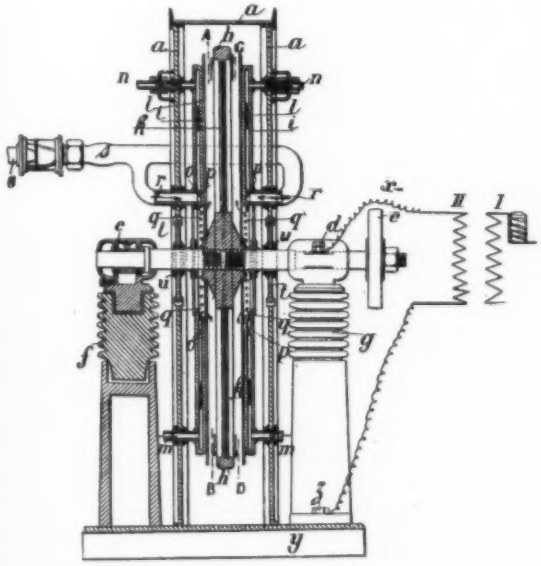


FIG. 4—OZONIZER.

serves as one of the electrodes of the apparatus and can be rotated around an axle *b*. Opposed to it are disks *i*, one on each side of *h*, which constitute the other electrode, and are covered with an insulating film or a lining of dielectric material *l*, on the side towards the revolving plate *h*. The disks *i* are hollow, for the purpose of being cooled by cold air or refrigerated water, entering through tubes *m*, *m*, and leaving through tubes *n*, *n*. Pipe *s* supplies air to the apparatus by its two branches, which air enters the inclosed space between the movable electrode *h* and the disks *i*, and there receives the diffused discharges, which shoot across the space between the electrodes. The oxygen of the air is by this means partially transformed into ozone. I designates the primary of a transformer, at low tension, and II is the secondary, at high tension, of that transformer. The air-containing ozone is drawn off at the bottom of the apparatus.

Ozonizing Apparatus. Alexander Vosmaer, Haarlem, Netherlands. Patent No. 709,427, September 16, 1902. Application filed October 4, 1901.

This apparatus is also an ozonizing apparatus, of simple construction, in which the electrodes are completely independent of the casing of the apparatus in which the air circulates, and from which they can be easily removed and replaced when necessary. The arrangement consists of two electrodes placed horizontally into a tube, preferably an ordinary gas pipe. The electrodes comprise a metal bar, of any suitable metal, of square or rectangular section, in which are fixed at intervals supports of insulating material, like porcelain, having at their upper part a fork, in which rests the other electrode. This other electrode the inventor designates as the discharger, and it is provided with a number of pins or points. The current of air to be ozonized enters at one of the ends of the upper tube and passes out through the other, consequently circulating in the plane wherein the electric discharges take place. This arrangement comprises one complete unit of the apparatus, and it is obvious that the apparatus may consist of a number of similar tubes, having a common inlet and outlet. An apparatus of considerable power can thus be easily constructed by arranging the tubes in a similar manner as in the crown sheet of a boiler or a surface condenser. The easy manner in which the electrodes can be replaced constitutes one of the principal advantages of the apparatus.

ELECTROCHEMISTRY AT THE WORLD'S FAIR, ST. LOUIS.*

BY W. E. GOLDSBOROUGH.

At St. Louis there is in process of development an International Exposition in which this Society can but be deeply interested. It will be brought to completion and presented for the education of the people of our country and the world at large, just at the time when the electrochemical industries of America will be acquiring that strength which will make them a most important element in our national life. Already I have heard it said by more than one distinguished foreigner, that America is regarded as having gained an unimpeachable position and prominence in the building up of this new industry, and I cannot but think our Society hears these admissions with no small degree of pride and satisfaction.

To my mind, it is right and highly desirable that an intimate knowledge of conditions should exist between the electrochemists and the officers of the Exposition. By the officers of the Exposition I am commissioned not only to extend to you a hearty invitation to participate in their great undertaking, but to go further, and assure you that in a most helpful spirit, they extend to you assurances of their great desire to place the resources of the Exposition at your command to the end of picturing in a way that will attract international attention, the true worth and vigor of this infant industry.

In accordance with the provisions of the official classification of the Exposition, the products of the electrochemical processes will be shown in several of the exhibit buildings. Manufacturers, liberal arts, machinery, and mines and metallurgy, as well as electricity, come in for a share of these products. And, indeed, it will be proper to exhibit certain electrolytic processes in the Palace of Liberal Arts, and certain others in the Palace of Mines and Metallurgy; but to electricity, in unrestricted measure, is accorded the privilege of giving expressions to all electrochemical operations, whether purely electrolytic in character, whether brought about by electrothermic means simply, or whether attained by a combination of electrothermic and electrolytic methods.

* Abstract of a paper presented before the Niagara Falls Convention of the American Electrochemical Society, September 17, 1902.

In the Department of Electricity one of its five groups is entirely devoted to electrochemistry.

Class 434 of this group is devoted to primary batteries, and storage batteries. In this class, in addition to an exhibit of the finished products, efficiency tests of batteries will be inaugurated and a careful record kept of their performance during the period of the Exposition. In addition to these, processes in the manufacture of various types of storage batteries will, it is hoped, be arranged for, in order that this matter may be pictured in a broad way.

Class 435 embraces electrolytic appliances and processes. All forms of electroplating, methods of electrotyping, and finally and most important, the applications of electrolysis in the reduction of ores and other related work, find place here; that this class presents the possibility of a most interesting and instructive series of exhibits will be at once recognized. Electrolysis plays an even greater and more important part in the business of the world each year. It has attained to a well-recognized position. Yet, with increasing emphasis, the work we see about us here at Niagara Falls, demands for it an even broader and more important recognition.

Class 436 deals with electrothermic appliances and methods, and, therefore, includes all of the electric furnace applications which we have found pictured in the great local factories on such a large scale. Nothing is more impressive than an inspection of the actual work of the electric furnace. We are in fact almost appalled in noting the wonderful results, both in magnitude and industrial importance, which are brought about by the dissipation of electric energy by these means, and its transformation into heat. The electric arc, when applied on a large scale, attracts and rivets the attention, not only of the initiated, but the uninitiated as well. It presents the picture of power in a most fascinating way.

Class 437 deals with the application of electricity to industrial chemistry, disinfection of sewerage water, manufacture of bleaching powder, caustic soda, nitric acid, chlorate of potash, etc., etc. Much can be done to make the exhibits in this class of great value and interest, not only to students, but to engineers and chemists. Some of the most interesting electrochemical operations find expression in the field of industrial chemistry, and a strenuous effort will be made to show all of its important divisions.

With the brief outline that I have given you, you will begin to appreciate the immensity of the task which is set for those servants of the Exposition, who will bring to its full realization the hope which I entertain for the success of the electrochemical group. That all the help and assistance which you as electrochemists can offer us will be most acceptable and gratefully received, it is hardly necessary for me to say. That I ask it, is because I believe you are as deeply interested as myself in having an adequate picture of what you are doing presented to the world. In my judgment a large and fine exhibit in this group will have a most beneficial effect upon the development along electrochemical lines. If, to-day, the financiers and people of the country generally had great confidence in the ability of electrochemists to carry to a successful issue all that is rightly claimed for electrochemistry, and if "electrochemistry" had become as much of a household word among our people, as have the technical terms employed in the older and better known branches of industry, it is safe to say that the money which will be investing in and about Niagara Falls within the next few years, would from the very force of the confidence of the general public, be augmented many fold. We, at the Exposition, are not therefore attempting anything that is illogical or unreasonable, when we plan to show all of the electrochemical processes I have mentioned in actual operation, and to show as many of them as may be possible on a commercial scale.

In the Electricity Building, as you doubtless know, space will be free to exhibitors, and provision has been made to supply exhibitors with free power within reason. The installation facilities are also all that can be asked, inasmuch as the railroad lines will be extended right into the Electricity Building during the period of installation, and traveling cranes and movable hoists will be provided over all of the principal aisles in the building.

At the present time the success of the exhibits in the Electricity Department can be said to be assured, inasmuch as a large number of most interesting working exhibits have already been arranged for in the allied branches. A maximum load of 2,000 horse-power will be available for the development for the working exhibits, and without doubt the building will teem with light and activity.

Within the next two years we will have time to give the topic which has been the subject of my talk the careful attention and thought which it needs, as well as the strenuous effort and labor which its development deserves. From the interest you have been good enough to manifest in what I have said, I feel assured of your helpful co-operation and advice in this very important department of my work, and I hope I have not lead you to expect anything that will not be fully realized.

In closing, I wish to say, that the chief of the Department of Mines and Metallurgy has extended to you through me the most cordial assurances of the interest which he takes in this work. It is his desire that in all its details the applications of electricity to metallurgy shall be given the fullest expression.

ELECTROCHEMICAL THEORIES ILLUSTRATED BY EXAMPLES FROM PRACTICE.

FARADAY'S LAW AND THE THEORY OF ELECTRONS.

The most puzzling point to the electrical engineer when he first undertakes the study of electrochemical problems is the very important part which the valence plays in Faraday's law. As an example, the final step of the Siemens & Halske copper process consists in depositing copper from a Cu SO_4 solution, while the final step of the Hoepfner process consists in depositing copper from a Cu Cl solution. With the same number of ampère hours, one obtains twice as much copper from the Cu Cl solution as from the Cu SO_4 solution. The reason is, of course, that Cu is monovalent in Cu Cl and bivalent in Cu SO_4. But to someone who does not fully understand the meaning of "valence" such a statement means nothing. For a full understanding of the part which the valence plays in electrolysis, it is necessary to approach the problem from the chemical side; it is then easy to apply the chemical theory of valence to electrochemical phenomena. In this way notations and terms which appear purely formal from the chemical point of view get a very substantial meaning when applied to electrochemistry.

Valence, Bonds.—The notation introduced by Prof. Otis C. Johnson is particularly suitable for our purpose. While for a detailed study of his notation the reader must be referred to Prescott and Johnson's "Qualitative Chemical Analysis," we will here briefly state the fundamental points. A bond—that is, a unit of *active valence*—is either a plus one or a minus one. The oxidation of an element is shown by an increase, and its reduction by a decrease of the number of bonds. Hydrogen (in combination) has always two negative bonds. Oxygen (in combination) has always two negative bonds. Free elements have no bonds. The sum of the bonds of any compound is zero. In salts the bond of the metal is always positive. In acids and in salts the acid radical has always negative bonds. These rules enable one easily to determine the valence in any compound. For instance, in HCl, H has one positive bond, hence Cl must have one negative bond in order to have the sum of all the bonds in the molecule equal to zero. In H_2SO_4, H_2 has two positive bonds and O_4 eight negative bonds, hence S has six positive bonds, or the radical SO_4 has two negative bonds. In our example noted above we had CuCl and $CuSO_4$. In CuCl, Cl has one negative bond, hence Cu one

positive bond. In $CuSO_4$, SO_4 has two negative bonds, hence Cu two positive bonds. In other words, Cu is monovalent in the first case and bivalent in the second case.

Johnson has also given the following simple rule for balancing equations which represent oxidation and reduction: "The number of bonds changed in one molecule of each shows the number of molecules of the other which must be taken, the words 'each' and 'other' referring to the oxidizing and reducing agents." One example may illustrate this rule, which appears to be purely formal from a chemical point of view, while its physical meaning will be shown below. In the Bunsen cell Zn is oxidized; it becomes $ZnSO_4$. The metal Zn has no bond. Zn in $ZnSO_4$ has two positive bonds, hence the increase in bonds is two. There are several actions possible at the other electrode. We may consider that of the development of NO. N in HNO_3 has five positive bonds, while in NO it has two positive bonds, hence the decrease in bonds is three. Now, Johnson's rule states that we have to take three molecules of Zn and two molecules of HNO_3, and we get the equation

$$3\ Zn + 3\ H_2SO_4 + 2\ HNO_3 = 3\ ZnSO_4 + 2\ NO + 4\ H_2O.$$

Faraday's Law.—The amount of electrochemical action produced (*i. e.*, of oxidation at the anode and of reduction at the cathode) is directly proportional to the product of ampère hours and the chemical equivalent. In other words, when a certain quantity of electricity (measured in coulombs or in ampère hours) passes through a certain electrolyte, a certain definite quantity of material is reduced at the cathode and oxidized at the anode. For instance, when 96,540 coulombs pass through CuCl, we know that one gram atom Cu is deposited upon the cathode and one gram atom Cl is liberated at the anode. We may form the following mechanical scheme as an illustration of what happens in the electrolyte. We may think that the passing of an electric current from the anode to the cathode is brought about by the cations Cu charged with positive electricity and giving off their charges to the cathode, and by the anions Cl charged with negative electricity and giving off their charges to the anode. We must then assume that in this case each gram ion Cu carries with it a charge of 96,540 positive coulombs, and each Cl ion 96,540 negative coulombs. When one gram atom Cu is deposited upon the cathode, it gives off its charge of + 96,540 coulombs, and at the same time one gram atom Cl is set free at the anode and gives off its charge of — 96,540 coulombs. In other words, 96,540 coulombs are taken off from the anode and given to the cathode, with the result that 96,540 coulombs "have passed through the electrolyte."

If we have $CuSO_4$, instead of CuCl, we know from experience that when $2 \times 96{,}540$ coulombs pass one gram atom Cu is deposited upon the cathode and one gram ion SO_4 reacts at the anode. In this case we must assume that one gram atom Cu is charged with $2 \times 96{,}540$ positive coulombs and one gram ion So_4 is charged with $2 \times 96{,}540$ negative coulombs. Cu is here bivalent, and has here twice the charge which it has in CuCl, where it is univalent. In general, *any gram ion is always charged with so many times 96,540 coulombs as it has bonds in Johnson's notation. Positive bonds represent a positive charge, negative bonds a negative charge.*

Johnson's rule of balancing equations representing oxidation and reduction becomes self-evident if applied to an electrochemical action. It simply means that just as much electricity passes from the anode into the electrolyte as from the electrolyte into the cathode. In the case of equation (1), if the chemical symbols represent gram atoms or gram molecules, then, as Zn gains two bonds and as we have three Zn atoms, $3 \times 2 \times 96{,}540$ coulombs pass into the electrolyte from the anode. On the other hand, N loses three bonds, and, as two N are reduced, $2 \times 3 \times 96{,}540$ coulombs are given off to the cathode.*

* Of course, we may consider HNO_3 to be ionized into H and NO_3 ions, both univalent, etc. The result is the same as above.

Faraday's Law and the Theory of Electrons.—We may go a step further and apply the modern theory of electrons to our problem. This has been done by Nernst. We will assume there are positive and negative electrons, although only negative electrons have so far been isolated. We may consider them as kinds of new elements (only for the sake of illustration), with so small atomic weights that, for all practical calculations, they may be considered zero; while their characteristic and distinguishing feature is that each positive electron has an electric charge of 96,540 positive coulombs, and each negative electron has an electric charge of 96,540 negative coulombs. Nernst, therefore, considers any univalent positive gram ion as a compound of the gram atom with a positive electron; also any bivalent gram ion as a compound of the gram atom with two electrons, and so on. This view emphasizes the essential difference between atoms and ions, and at the same time gives a very convenient scheme for applying Faraday's law. Johnson's bonds are, then, a very substantial thing. His positive bonds are positive electrons, and his negative bonds are negative electrons. This view, although it may be called very hypothetical, offers the safest method of applying Faraday's law. There is no possibility of making a mistake if we always keep the mechanical model in mind. Take our equation (1). As mentioned above, each Zn atom gains two bonds—that is, in our new model—while the Zn atom on the electrode has no inherent electric charge, the Zn ion in the solution (as we may consider the $ZnSO_4$ solution to be ionized into Zn ions and SO_4 ions) is combined with two positive electrons (because it has two bonds). Hence, if the symbols in equation (1) represent gram atoms or gram molecules, three gram atoms Zn become three bivalent ions, *i. e.*, get a charge of $6 \times 96{,}540$ coulombs. In other words, the equation (1) represents the chemical action if $6 \times 96{,}540$ coulombs pass through the system. If one only knows what the oxidation and reduction is at the two electrodes, one can calculate the whole matter. Johnson's rule for balancing equations enables one to write down the equation which represents the electrochemical action, and there is no mistake possible if one keeps in mind that each bond corresponds to 96,540 coulombs, if the chemical masses are measured in gram atoms or gram molecules.

CURRENT NOTES.

OUR esteemed contemporary, *The Engineering and Mining Journal*, announces that its chief editor, Dr. David T. Day, and its managing editor, Mr. E. W. Parker, have resigned, the former on account of the urgent demands of his work on the Geological Survey and the latter on account of the onerous work and the responsibility devolving upon him as a member of the Anthracite Coal Strike Commission. The new editor will be Mr. J. A. Rickard, with Messrs. F. Hobart, J. Struthers and S. Sanford as associate editors and Messrs. R. W. Raymond, W. R. Ingalls, J. A. Church, R. A. F. Penrose, Jr., S. F. Emmons, W. H. Weed, P. Argall, A. G. Charleton and D. J. Day as "special contributors."

THE eighty-third meeting of the American Institute of Mining Engineers was held in New Haven, Conn., from October 14th to 17th. The list of members and guests registered comprised about 60 names. (At the last Niagara meeting of the much smaller American Electrochemical Society about 160 members and guests had registered.) Some 20 papers were read, partly in title. Among the papers read was one by Dr. Leonard Waldo, on the measurement of high furnace temperatures, in which he pointed out the many important applications of the pyrometer. Visits were made to the Yale University, and especially the Peabody Museum, and a geological excursion was made to West Rock.

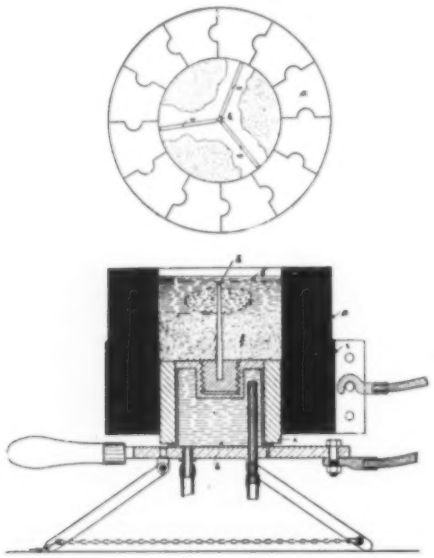
SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

By Carl Hering.

INDUSTRIAL ELECTROCHEMISTRY.

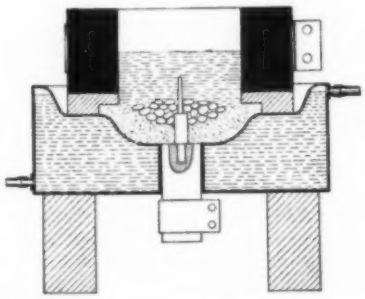
Metallic Calcium.—The production of calcium from its compounds by electrolysis has generally been considered to be very difficult, and it is therefore of some interest to see that Borchers and Stockem have succeeded in producing metallic calcium from some of its compounds, on such a scale that the process is claimed to be applicable on a commercial scale. The



Borchers and Stockem Calcium Furnace.

question naturally arises, what is to be done with this metal, which is not now used in that form? But, like in other similar cases, the reason why it has not been used is probably because it was not a cheap commercial article, and when it becomes so good uses for it will no doubt be found. Their process is described, with illustrations, in the *Zeit. f. Elektrochemie*, October 2, 1902. They have found that it is quite easy to deposit large quantities of calcium, by electrolysis, of electrically-fused calcium chloride, which is free from water. They use a small cathode opposite a large anode, and keep the temperature at a red heat above the melting point of calcium chloride, but below the melting point of metallic calcium; the calcium is then deposited at the cathode in a spongy form. This sponge forms such a coherent mass that it can be easily removed from the cell. If the sponge is then at once put into a suitable liquid, free from oxygen, one obtains a sponge of 50 or 60 per cent. free metallic calcium, mixed with calcium chloride. If the sponge is pressed before it is removed from the cell, it welds itself into a dense, bright mass, containing about 90 per cent. of calcium. Instead of calcium chloride, other calcium salts, especially calcium fluoride, may be used. The addition of calcium fluoride to calcium chloride has no unfavorable action; the authors prefer to use calcium chloride because it is cheap, and it has such a melting point that by exceeding it slightly one at once obtains that temperature which is best for the formation of the coherent sponge without necessitating careful temperature measurements. If the temperature is raised beyond the melting point of calcium, there are unnecessary heat losses and a tendency to re-dissolve the deposited metallic calcium, presumably by the chlorine gas. The apparatus used by the authors is shown in the adjoining diagram. The case, containing the fused salt, is the cylinder *a*, which consists of carbon rods put together like the pieces of wood of a wooden barrel, and held together by a metallic ring *r*. This forms the anode and connection to the external source of current made through the metallic ring *r*. The cylinder is closed at the bottom by a cooling apparatus *h*. The cathode consists of an iron rod *k*, placed into the cooling apparatus, the frame of the latter forming the connection with the negative pole of the source of current. The iron cylinder *a* and the cooling apparatus *h* are, of course, separated from one another by an insulating layer *i* of clay or other suitable refractory material. The lower part of the case is filled with compressed calcium fluoride *f*, the greatest part of which remains solid during the operation, on account of its higher melting point, and because it is cooled from *h*. In this way the fused chloride of calcium is protected against coming into contact with and receiving impurities from the bottom of the case. Above the fluoride there is placed the calcium chloride *c*. In order to fuse it and to start the process, several thin carbon rods *w* are provided, which short-circuit the cathode *k* with the anode carbon cylinder. When the circuit is closed, the current melts the top of the calcium chloride, after which the rods *w* are removed and the electrolytic operation is started. They mention briefly that in afterwards treating the calcium thus produced, they obtain crystals which seem to be CaCl.

Pure Strontium.—These same experimenters have also shown how pure strontium may be produced in a very similar way, the illustrated description being in the same number of that journal. It is a short article, in which they say that they have succeeded in using this calcium apparatus, just described, with a slight modification, for the production of pure strontium in large quantities. By electrolyzing electrically-fused strontium chloride in their calcium apparatus, they obtained metallic strontium, not in the form of sponge, but in form of fused globules, of about the same specific gravity as the bath. Much strontium was mechanically transfused to the anode, and this represents losses, causing a poor ampère-hour efficiency. The apparatus was therefore modified, as shown in the adjoining

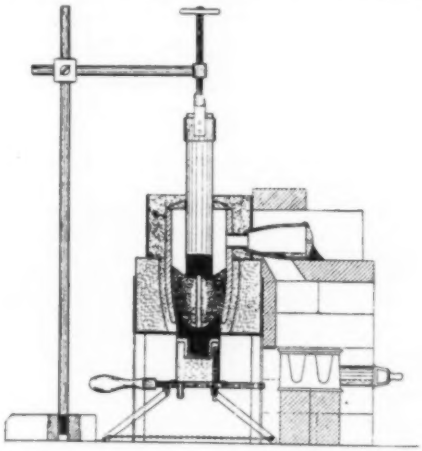


Borchers and Stockem Strontium Furnace.

diagram. The cathode, which was an iron rod, passes up from below through the cooling apparatus, but only to such a height that it is about at a level with the carbon cylinder, which forms the anode and rests upon an insulating ring, which separates it from the cooling apparatus. The bottom of the case is filled with a solid mass, with a pit in the center part, in which the strontium deposited at the cathode in form of globules remains

at rest and becomes solid, as it is cooled from below. In the lower part of the solid mass globules of pure metallic strontium are found, of diameters up to 10 mm., after the electrolysis is finished. Strontium is, like calcium, a white metal, and just as soft as lead.

Reducing Zinc from its Ores.—The production of zinc from its compounds involves difficulties due to the very electropositive nature of that metal, or, to put it into more modern terms, on account of the high value of the energy of combination of zinc compounds. In electrolysis this means the use of such high voltages that other undesirable reactions take place, for which that voltage is more than sufficient. In aqueous solutions, for instance, hydrogen is liberated much more easily than zinc. Such processes are therefore of special interest; all the more so as the electric methods have not yet come into use as much as might be expected. In a recent article in the *Zeit f. Elektrochemie*, September 25, 1902, DANNEEL describes several zinc processes which were worked out at the metallurgical laboratory of the Institute of Technology of Aix-la-Chapelle, Germany. The first one is devised by Borchers, the director of the laboratory, and Dorsemagen. They chlorinate raw ore in the presence of salt solutions, such as sodium chloride and magnesium chloride, in revolving iron drums, lined with lead, at a temperature of 30° to 40° C., by means of free chlorine, obtained in another part of the process. The chlorides of lead, zinc and silver are then leached out with hot water or hot dilute lyes, obtained during the process. The following data



DORSEMAGEN FURNACE FOR THE PRODUCTION OF ZINC AND SILICON CARBIDE.

of a test are given: 1,000 kg. ore contained 140 kg. lead, 310 kg. zinc, 0.69 kg. silver. There were chlorinated and leached out 140 kg. lead, 175 kg. zinc, 0.11 kg. silver. In the residue there remained 135 kg. zinc, 0.53 kg. silver and 115 kg. sulphur. After the extraction of the sulphur, there remained a residue of 39.1 per cent. zinc and 0.168 per cent. silver. From the residue, the sulphur is removed by Schaffner's method under steam pressure. The chloride lyes are purified by means of zinc oxide or roasted zinc ore, evaporated to dryness and dehydrated as completely as possible. The dehydrated mixture of chlorides is then electrolyzed in a fused state, and at the anode the chlorine gas is obtained which is used in another step of the process, as mentioned above; while at the cathode a mixture of molten lead and zinc is produced, which is obtained in two alloys—lead poor in zinc and zinc poor in lead. From the lead which is poor in zinc, the zinc can be removed by steam; the zinc which is poor in lead is refined by distillation. A large experimental plant for studying this process on an industrial scale is being installed by F. Krupp.

The second process described was devised by Borchers and von Kuegelgen, and is for treating the waste from zinc galvanizers. This waste is dissolved in hydrochloric acid to saturation. The iron is removed from the solution by means of chloride of lime and other oxidizing agents; it is then evaporated to dryness in iron crucibles lined with lead. The pulverized zinc chloride is mixed with metallic oxides—for instance, copper oxide and calcium carbide—and is then melted to zinc alloys—for instance, brass. The reaction between zinc chloride, metallic oxide and calcium carbide goes on by itself, owing to its own heat of reaction, after the reaction has been started by means of an incandescent body; but to obtain good metal it is necessary to heat the crucible.

The third process described was devised by Dorsemagen, for the treatment of siliceous zinc ore, especially if the percentage of zinc is small; zinc and silicon carbide (carborundum) are produced. An electric furnace is used, as shown in the adjoining diagram. A mixture of carbon and siliceous zinc ore is heated in the furnace by a carbon rod; the zinc is distilled off, and there remains silicon carbide. The reduction temperature of the silica is only slightly above the distillation temperature of zinc.

The fourth process described is by Borchers and Dorsemagen, and is quite analogous to the last one described. It is used for the treatment of ores containing iron and zinc, in order to get ferrosilicon and iron. The process differs from the last one only in so far as ferrosilicon, instead of silicon carbide, is obtained.

Lead Refining.—Lead is being refined from its bullion by the Betts process, in a plant having a capacity of about 10 tons daily. It is said to have a low working cost and a high efficiency. This plant is described by ULKE in the *Engineering and Mining Journal*, October 11, 1902. The general arrangement of the plant is very similar to that of a copper refinery. The success of the process is based upon the solubility of lead in an acid solution of lead fluosilicate, which has both stability under electrolysis and high conductivity, and from which very pure lead is said to be deposited with impure anodes at a very low cost. The solution is obtained by diluting hydrofluoric acid of 35 per cent. H. F. with an equal volume of water and saturating it with pulverized quartz. The anodes consist of the lead bullion to be refined, cast into plates about 2 inches thick. The cathode sheets, which receive the regular lead deposits, are thin lead plates, obtained by electrodeposition upon and stripping from special cathodes of sheet steel. The anodes and cathodes are separated by a space of 1.5 to 2 inches in the tank; the tanks are in series; the fall in potential between tanks is only 0.2 volt. Current densities of from 10 to 25 ampères per square foot have been used, but 14 ampères have given the most satisfactory results. According to the inventor, "260,000 ampère hours at 0.25 volt works out to 87 electric horse-power hours, or 100 horse-power hours at the engine shaft, in round numbers. Estimating that 1 horse-power hour requires the burning of 1.5 pounds of coal, and allowing, say, 60 pounds for casting the anodes and refined lead, each ton of lead refined requires the burning of 210 pounds of fuel." Practically all the impurities in the base bullion remain as a more or less adherent coating on the anode, and only the zinc, iron, cobalt and nickel practically go into solution. The anode residue consists practically of all the copper, antimony, bismuth, arsenic, silver and gold contained in the bullion, and very nearly 10 per cent. of its weight in lead. The silver slimes obtained, averaging about 8,000 ounces of gold and silver per ton, are now treated at the Seattle Smelting and Refining Works.

Copper Depositing.—A description of the Dessolle process of copper plating, in which the electrolyte is projected under pressure against the metallic object and the anodes, is published in a recent number of the *Jour. Soc. Chem. Ind.*, an abstract of which may be found in the *Lond. Elec.*, October 3, 1902. The metallic objects are first cleansed, either in an acid bath or by means of a jet of sand driven by compressed air, which rapidly removes all impurities. They are next placed in a preparatory bath and subjected to the action of a current of 30 ampères per square meter. The composition of this so-

called "adhesion bath" is as follows: Double cyanide of potassium and copper, 4 parts; potassium cyanide, 0.5 part; ammonia, 0.5 part; water, 94 parts. On leaving this bath, the objects are carefully examined, and any trifling holes in the deposit stopped with solder, or, if larger, with spongy tin, obtained by electrolysis. They are next immersed in the principal bath, which has the following composition: Crystalline copper sulphate, 12; free sulphuric acid (66 degrees), 3; water, 85 parts. Jets of this liquid are driven against the surface and that of the anodes. This effects a removal of gas and impurities from the bath and enables a strong current to be used, so that a perfectly smooth deposit of copper is obtained. In Dessolle's installation a current with an ampèrage of 750 is employed, and a deposit of 1-10 mm. is obtained in one and one-half hours, a rapidity of deposit which is stated to have no prejudicial effect upon the quality. The temperature is maintained at the required degree by means of steam jets, viz.: at 50° C. in the adhesion bath and at 35° C. in the final bath. The electrolyte projected by the jets falls into a central tank below, whence it is raised by means of wooden pumps to a reservoir fixed at a height of 5 meters above the level of the bath, and falls through the jets again under considerable pressure. Finally, the plated articles are dried and polished in the usual way. The price of plating metals with a good deposit of copper does not exceed 2 fr. per kilogramme of deposit, but the economic advantage of the Dessolle process is that there is perfect adhesion of the deposit, which can be made thicker and yet be durable.

There is another, but very short, article on the use of copper deposits to hold together pieces of glass, by forming a sort of beading on the edges of copper strips placed between the edges of the pieces of glass or prisms, by which means composite structures, like reflectors or refractors, are built up. The method seems to be used in place of the usual burned lead strips in colored-glass windows. It is very briefly described in the *Lond. Elec. Rev.*, October 10, 1902.

Manufacture of Aluminum.—A Bunsen Society paper, in which Haber describes a series of experiments to show on a small scale the principal points which are of importance for the success of the manufacture on a large scale, is given in the *Zeit. f. Elektrochemie*, August 21, 1902.

Graphite.—The change of amorphous carbon into graphite was known to have occurred at the high temperature of the arc, but it was not until Acheson discovered the necessary intermediate action that it became possible to succeed in doing this commercially. He showed that to bring about the change it was necessary to first form some compound of carbon and then dissociate this, setting free the other element. The carbon which remains will then be in the form of graphite. Danneel, in the *Zeit. f. Elektrochemie*, September 25, 1902, gives an account of an investigation of this transformation by Borchers and Moegenburg. They found, as Acheson did, that this conversion is very difficult when absolutely pure carbon is used, but it is greatly accelerated if metals or metallic compounds are present which are able to form more or less dissociable carbides. During dissociation the metal is evaporated, and the carbon remains as graphite. They have studied the use of iron, manganese and aluminum for this purpose, and have found that iron is least suitable, while aluminum is the most convenient and effective material. Although the reduction temperature of aluminum oxide is somewhat above that of manganese oxides, yet aluminum is more volatile than manganese. The quantities of aluminum or aluminum oxide required are relatively small. Aluminum is even considerably more effective than boric acid, phosphoric acid, etc.

Chlorates.—J. B. C. Kershaw's second article on electrolytic manufacture of chlorates is published in the *Elec Rev.*, October 11, 1902. In this part he discusses the Corbin cell and the Franchot and Gibbs cell, and makes some remarks on the efficiency of the various processes. He gives an estimate of the cost of chlorate of potash, made in a 3,000 horse-power hydroelectric plant, producing 1,600 metric tons of chlorate. The cost per pound of chlorate is 4.7 cents. He then gives a summary of numerous laboratory investigations bearing on the theory of chlorate cell. Foerster, Mueller and Jorre state that the reduction of the cathode can be suppressed either by use of calcium chloride or of potassium chloride. The electrolyte should be slightly acidified to liberate hypochlorous acid. A large volume of electrolyte should be used, and should be kept in vigorous agitation, in order to allow the secondary reactions to occur as rapidly as possible. The temperature of the electrolyte should be maintained above 40° C. to promote circulation, to reduce the e. m. f. and to diminish the formation of perchlorates, which otherwise would occur. Tucker and Moody electrolyzed calcium chloride solutions, and recommended that the solution should be one of 20 per cent.; the electrodes should be of platinum, horizontal, and 10 cm. apart; the current density should be 8 ampères per square decimeter at the anode; the temperature should be maintained at 80° C.; sodium chromate or sodium hydrate should be added to the electrolyte. Foerster and Mueller state that the best efficiency is obtained when an electrolyte is used containing sodium chromate and free hydrochloric acid, in conjunction with a spongy platinum electrode. Under these conditions, two-thirds of the chloride present in the cell can be converted into chlorate, with a current efficiency averaging over 94 per cent.

Calcium Carbide Patents.—It is certainly a tribute to electrochemistry when an article which was almost unknown only a few years ago is now manufactured in Europe in such large quantities that it becomes necessary to force a market for it in some other country by annulling the patent in that country, yet, according to a report in the *Lond. Elec. Rev.*, October 10, 1902, this is what the United Carbide Factories of Nuremberg, Germany, which is presumably the carbide trust of Germany, have decided to try to do with the Willson patents here in the United States. The European and American patents are discussed at some length.

Alizarine Industry.—Alizarine was formerly obtained from the root *Rubia Tinctorum*, but, since Grabe and Liebermann discovered that alizarine is a derivative of anthracene, it has been manufactured from coal tar by treating anthracene with sodium bicarbonate and sulphuric acid. This gives anthraquinone, and, according to the modern process, this is treated with fuming sulphuric acid, and the monosulphite is found with caustic soda. To obtain anthraquinone from anthracene, sodium bicarbonate is necessary. Up to the present the methods for recovering the chromium salt contained in the mother liquor as chromium sulphate have been very troublesome. The electrolytic recovery has hitherto been hindered by the fact that a diaphragm is necessary between the two electrodes, and that none was found capable of withstanding the strongly acid solution for any length of time. This difficulty is said by Simon, in the *Jahresber. Phys. Ver.*, Frankfort, 1902, to have been overcome by Leblanc's invention of diaphragms, consisting of 25 per cent. alumina and 75 per cent. silica, which not only are very durable, but also have a low resistance. One German aniline dye factory has been transferred to the neighborhood of Augsburg, where sufficient water-power is available to yield a cheap supply of electrical energy for the new process. An abstract of the article may be seen in the *Lond. Elec.*, October 3, 1902.

THEORETICAL AND EXPERIMENTAL.

Electrolysis of Fused Sodium Hydroxide.—Although NaOH is usually an end product of electrolysis, and not a raw material for electrolytic conversion, yet it is of interest to know what will occur when it is electrolyzed. In the *Zeit. f. Elektrochemie*, September 11 and 18, 1902, Le Blanc and Brode give a long account of an experimental investigation of this, the principal results of which may be summed up as follows: Fused sodium hydroxide containing water has two distinct values of decomposition voltage, 1.3 and 2.2 volts. In baths which are free from water, the lower decomposition

voltage disappears. By quantitive measurements of the gases developed during electrolysis at different voltages, they found that both values of the decomposition voltage have a real meaning. At 1.3 volts there is a development of hydrogen and oxygen, while at 2.2 volts sodium and oxygen are set free. The ampère hour efficiency of the oxygen increases with increasing current density. Below 2.2 volts the efficiency of the development of hydrogen is 100 per cent. as long as no free sodium is present. In a bath free from water, and with a voltage above 2.2 volts, the cathodic deposition is only sodium. It is certain that pure fused sodium hydroxide contains no H or O ions, but only Na and O H ions, the latter producing water and oxygen by secondary reaction. The phenomena of the electrolytic production of sodium by the Castner process on a large scale are also discussed.

Electrolysis of Alkaline Chlorides.—FOERSTER and MUELLER give a long account of a series of experiments in the *Zeit f. Elektrochemie*, August 28 and September 4, 1902, the main results of which are as follows: If equimolecular solutions of alkali hydrate, hypochlorite and chloride are electrolyzed with increasing voltage, the passage of a certain current takes place through the hydrate solution at the lowest anode potential and through the chloride solution at the highest anode potential. At an intermediary anode voltage, characteristic for the electrolysis of hypochlorite, a discharge of univalent negative Cl ions take place. At the moment of the anodic discharge univalent negation Cl ions react with water and form chloric acid, hydrochloric acid and a development of oxygen at the anode. The anodic formation of chlorate takes place as well with solutions containing free hypochloric acid as with neutral or alkaline solutions of hypochlorites. A secondary formation of chlorate takes place in the electrolysis of the hypochlorite if the electrolyte has become somewhat rich in free hypochlorous acid.

Electrolytic Reduction of Nitric Acid.—An investigation of the alterations which nitric acid will undergo by electrolysis in the neighborhood of the cathode, when considerable amounts of sulphuric or hydrochloric acid are present, is described by TAFEL in the *Zeit. f. Anorgan. Chemie*, 31, 3, p. 289, 1902, an abstract of which is given in *Science Abstracts* for September, 1902. He found that a reduction will occur with most cathodes, excepting, for instance, platinum. The mean products of this process are ammonia and hydroxylamine, their ratio depending on a whole series of factors and varying to a high degree, according to the nature of the cathode, whereas the sulphuric and hydrochloric acids do not seem to exhibit any marked differences. The largest amounts of hydroxylamine are evolved with pure mercury cathodes or well-amalgamated electrodes, the formation of ammonia being almost wholly prevented in some cases, so as to obtain a nearly perfect quantitative transformation of nitric acid into hydroxylamine salt; whereas in the case of lead cathodes the amount of the acid transformed into hydroxylamine was not higher than 40 per cent.; for copper, 15 per cent. at the most. The rate of this reduction is smallest in the case of copper electrodes. It is next shown that, with electrodes giving rise to this reduction process, hydroxylamine sulphate will equally be reduced, and *vice versa*.

Ozone.—The electromotive behavior of ozone has been studied experimentally by Inglis, an account of which is given by LUTHER in a recent Bunsen Society paper, published in the *Zeit. f. Elektrochemie*, August 28, 1902. In this description Luther gives nine results obtained with an ozone electrode; that is, an electrode of platinized platinum in a solution of ozone. He found that such an electrode assumes a higher oxidation potential when the electrode was previously charged with hydrogen, and a lower one if thus saturated with oxygen. He also shows an experiment which at first sight seems very strange, as there is reduction at both electrodes, and this is contrary to one of the first principles of electrolysis, namely, that there is always oxidation (or, better, "perduction") of the electrode or the solution, or both, at the anode and reduction at the cathode. The reduction at the anode in this exceptional case is explained as a secondary action, due to a primary oxidation with a formation of a higher oxide, which is, at the same time, a more energetic reducing agent. This explanation seems quite a reasonable one.

Electric Double Layer and Absolute Potential.—As we cannot connect a measuring instrument, which is usually of metal, with an electrolyte without using two electrodes, it follows that all measurements of electrolytic potentials give only the algebraic sum of the two potentials at the two electrodes. It seems very difficult to find some way of measuring each separately, although several more or less doubtful methods have been suggested. It is evident that the algebraic sum of two quantities can never define the two quantities themselves, as they may both be very large or very small and yet have the same algebraic sum. Sometimes the so-called hydrogen electrode is taken as zero, from which the potential difference of any other individual electrode with an electrolyte can be determined, but this is, of course, an arbitrary scale and not an absolute one. BILLITZER has attacked the problem in a different way. As described in his recent Bunsen Society paper, published in the *Zeit. f. Elektrochemie*, August 28, 1902, he endeavors to find the conditions under which the potential difference between an electrode and an electrolyte is zero. It is based upon Helmholtz's theory of the relation between potential difference and electric "double layer," or, in German, "Doppelschicht." In the discussion which followed, it was pointed out that Helmholtz, starting from the same foundation, devised another method, and that Ostwald's and Billitzer's methods, although based upon the same grounds, give very different results. The whole matter is therefore, unfortunately, still entirely in the dark. Haber called attention to another method, which had been proposed by the late Luggin. Nernst proposed to consider the whole matter as hypothetical, and to use a convenient, although arbitrary, zero point by assuming the potential difference at the hydrogen electrode equal to zero.

Free Ions.—An account of an experimental investigation into the existence of free ions in aqueous solutions of electrolytes is given by OLSEN. After some critical remarks on an older experiment by Ostwald and Nernst, he describes some experiments which he has made, and which are based on the following considerations: It is believed that an electrostatic charge attracts and repels the unlike and like charged ions respectively; and as it is the ions which, in giving up their charge, produce a current, then, if these ions can be guided by an electrostatic charge, we should get a current with electrodes indifferent to the solution, and be able to detect it with a sufficiently delicate galvanometer. The results of the experiments are given as follows: When a cell containing an electrolyte is connected to a Danneel element, although the e. m. f. is below the decomposition value of the electrolyte, the solution in the neighborhood of the anode becomes positive, or, in the neighborhood of the cathode, becomes negative, or both. After an electrolyte has been electrolyzed by a current, it is affected by an electrostatic charge in such a way that the liquid nearest the charge becomes of the opposite sign, or the liquid farthest from the charge becomes of the same sign as the charge, or both, *i. e.*, an electrolyte, after having been electrolyzed, acts as if it contained particles charged with electricity, which are free to move and may be directed by an electrostatic charge. An electrolyte subjected to an e. m. f. less than the decomposition value of the solution behaves in a similar way. Finally, an electrolyte which has never been acted upon by a current also behaves in a similar way when acted upon by an electrostatic charge, *i. e.*, it behaves as if it contained particles charged with electricity, which are free to move, and these particles have not been produced by a current. This corresponds to the definition of free ions. The paper is published in the *Am. Jour. Sc.*, October.

MISCELLANEOUS.

Among the other recent articles may be mentioned one by Ley, on the application of electrochemical methods to the determination of the structural formulas of silver salts, in the *Zeit. f. Elektrochemie*, September 4, 1902; a Bunsen Society paper by Zsigmondy, on colloidal solutions, chiefly on the order of magnitude of the dimensions of the particles, and especially of gold, in the same number. An illustrated description by Jordis of a mercury bath for lecture-room purposes, for showing the vapor tensions of solvents and solutions by means of a series of barometer tubes, which is also in the same number of that journal.

PRIMARY AND SECONDARY BATTERIES.

The Prospects for a Light Storage Battery.—In the opinion of Norden, the lead accumulator has been so much improved in recent years that there is not much room for further progress, and the "light accumulator of the future" must be a non-lead accumulator. In his article, which is published in the *Centralblatt f. Accum.*, August 15, 1902, he first discusses former trials with metals different from lead. The zinc lead peroxide cell has a higher ampère hour capacity per pound of weight, and its discharge voltage is higher than 25 per cent. But the disadvantage is that during discharge the zinc goes into solution, and during charge it is not so perfectly and cleanly redeposited, but sometimes in spongy form, which may cause short circuits, and it is therefore impossible to avoid irregularities entirely. Moreover, local action at the zinc plate cannot be entirely avoided, in spite of amalgamation. What is said here about the zinc electrode is generally valid for any soluble electrode, as in practice there will always be trouble in redepositing the metal. He therefore claims as a general principle that a soluble electrode is unsuitable for a storage battery. He then discusses the cuprous oxide zinc accumulator, in which there is again the same trouble with the zinc. The copper plate also has disadvantages; it ought to be insoluble in the electrolyte, but at the end of the charge cupric, instead of cuprous, oxide is often formed. And as soon as a trace of cupric oxide goes into the solution, copper becomes an ion, and is deposited on the zinc, causing a fatal local action at the zinc plate, as it there forms a short-circuited copper-zinc couple. It has often been concluded that the use of two different metals is therefore impracticable in an accumulator, but this conclusion would be wrong, for if both metals are absolutely insoluble there would be no danger whatever. Moreover, the last-discussed disadvantage occurs only when the metal which is dissolved can be deposited upon the opposite pole. This is, for instance, not the case with the zinc, as it never can be deposited upon the opposite plate. He therefore claims, as a second principle, that two different metals in an accumulator are practical only when they are either both insoluble in the electrolyte or when, if dissolved, they cannot be re-deposited on the opposite plates. He then discusses the Edison accumulator, which he considers to be a step in the right direction, although he does not think that it represents the definite solution of the problem of the light accumulator. The mechanical construction, with the active material compressed in perforated boxes, is not thought to be the best construction for utilizing the total active mass, as the passage of the current into the interior of the boxes and the diffusion of the electrolyte into the pores is somewhat difficult. He thinks that the capacity of the Edison cell per pound of weight is too nearly of the order of magnitude of that of the lead cell. A new principle has not been found in the invention of the Edison accumulator, but its general importance is that it shows that with an old method, which has already been considered as being without prospects, some success can be obtained. He finally points out the impossibility of predicting anything concerning the probable future development from a purely theoretical point of view.

Tribelhorn Storage Battery.—It is an old device to make up a series of batteries by making the cells in the form of metallic dishes piled one over the other, with insulating separators, so that the lower surface of the upper dish is one electrode and the upper surface of the lower dish is the other electrode, the liquid being filled into the dishes. This idea, although ingenious, seems to have survived only in the Tribelhorn accumulator, made in Switzerland, and said to be used in factories, hotels and central stations. Its characteristic feature is the arrangement of the cells, which are in the form of leaden conical dishes, one above the other (quite similar to Salom's arrangement for lead reduction, recently described in these columns). The upper side of each dish is positive, the lower negative. The novel device is that the active material is keyed in peculiarly-formed furrows on both sides of the dishes. The charging voltage increases to 2.75, and the discharge voltage decreases to 1.85 at slow discharge and to 1.72 at fast discharge. The ampère-hour efficiency averages 90 to 92 per cent., and the watt-hour efficiency 68 to 70 per cent. The description, with illustrations, may be found in the *Elek. Neu. Anz.* for October 1, 1902.

Accumulators.—The *Centralblatt f. Accum.*, September 1, 15 and October 1, 1902, contains continuations of the descriptions of the accumulator exhibits at the Dusseldorf Exposition by the following German firms: E. Schulz, of Witten; the Pollack Accumulator Works, of Frankfort; also an exhibit by the "Accumulatoren Fabrik A. G. Hagen," on sanitary arrangement in storage-battery factories.

E. M. F. of Ozone Cells.—An account of an investigation of the question whether the heat produced by the decomposition of ozone—which, according to Berthelot, is 29,600 gram calories per 48 grams of ozone—can be utilized wholly or in part for the production of electrical energy is given by Brand in the *Ann. d. Phys.* No. 10, 1902, abstracted in *Lond. Elec.*, October 10, 1902. A Grove gas battery can be constructed with oxygen and ozone as elements, the current passing from the oxygen electrode through the electrolyte to the ozone electrode. To determine how much of the energy is thus transformed, it was necessary to find the e. m. f. of the cell. But, since the e. m. f. of an oxygen cell is not constant, the e. m. f. of the oxygen electrode and of the ozone electrode were determined separately by comparison with a normal mercury electrode, consisting of mercury covered with mercurous sulphate and immersed in normal sulphuric acid. Eventually the author obtained an amount of energy equal to 0.5 joule per coulomb. The total work of ozonization amounts to 0.642 joule per coulomb, so that there is a rather high electrical efficiency.

Standard Cells.—A German Bunsen Society paper, by Cohen, on the changes of the cadmium amalgam in Weston cells under certain conditions, and on the electromotive behavior of cadmium amalgams, is given in the *Zeit. f. Elektrochemie*, August 28, 1902.

GENERAL AND MISCELLANEOUS.

Magnetic Concentration.—Hassreidter gives a description of the Mechernich system of magnetic concentration in the *Jour. Soc. Chem. Ind.*, September 30, 1902, an abstract of which will be found in the *Eng. and Min. Jour.*, November 1, 1902. The ore is delivered by an adjustable chute between two magnetic poles, the upper one of which (the north pole) is rotated. As the ore arrives in the magnetic field, the permeable particles are attracted by the north pole, and are carried around by it into zones of progressively diminishing intensity, until the centrifugal force imparted to the particles overcomes the magnetic attraction and they fall into collecting chutes, being classified according to their magnetic properties. The non-magnetic material falls directly into a chute close against the lower pole. This arrangement is claimed to have the advantages of dispensing with belt carriers, which weaken the magnetic field; and also of permitting the use of small magnetic fields and very narrow air spaces, thus minimizing the loss of energy and making it possible to attract feebly magnetic

particles by a very weak current. The rotating pole being the only moving part of the machine, the wear and tear is very small. In separating blende and siderite from the Upper Harz, the grains being of 0.5 mm. size, 98.7 per cent. of the zinc has been recovered. With dolomitic Silesian blende of 2 to 3 mm. size, the recovery was 91.8 per cent., which was increased to 93.5 per cent. by reducing the grains to 2 mm. In treating ore from Broken Hill, a yield of 81 per cent. of the lead and 69 per cent. of the zinc was obtained. A plant of this type installed at Broken Hill for the treating of middlings, assaying 28 per cent. zinc, 10 per cent. lead and 9 ounces silver per ton, furnishes a product with 44 to 45 per cent. zinc and 4.5 per cent. lead.

Electrochemistry at the Dusseldorf Exhibition.—DANNEEL, in the *Zeit. f. Elektrochemie*, September 25, 1902, begins a long illustrated descriptive article, in the introduction of which he describes the geology, minerals, coal mining, ores and mining installations in general in the few western provinces of Germany from which most of the exhibitors come. He then discusses the exhibits of the Aix-la-Chapelle Institute of Technology, and describes several metallurgical processes which have been worked out in its metallurgical laboratory. Abstracts of these descriptions will be found in other paragraphs of this synopsis.

Analysis of Foodstuffs.—An article by MEDICUS, giving an account of experiments made by Mebold on the electrolytic determination of traces of metals in foodstuffs, is given in the *Zeit. f. Elektrochemie*, September 4, 1902.

SOME EUROPEAN ELECTROLYTIC POWER PLANTS.

BY FRANK C. PERKINS.

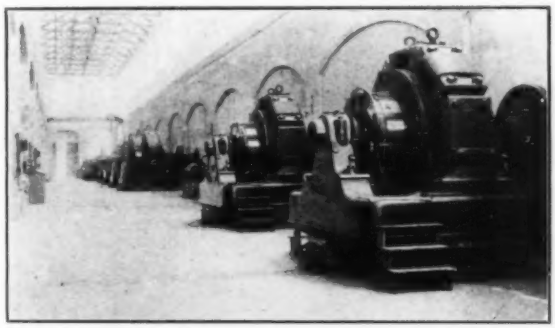
The water-powers of Switzerland which have been developed have been very extensively used for electrolytic work. The Swiss electrical manufacturers, as Brown, Boveri & Co., of Baden, and the Compagnie de L'Industrie Electrique, of Geneva, as well as the firm of Ganz & Tarsa, of Buda-Pesth, Austria-Hungary, have designed many special machines for electrolytic purposes. Among the important power plants using Swiss apparatus for the production of chlorate of potash may be mentioned those at St. Michel, Vallorbes and Cheddes, and for soda and chlorine the Usine de Gavet-Clavaux and the Usine de Monthey, Switzerland.

The Usine de Cheddes supplies the necessary power for the electrochemical production of chlorate of potash, and is located in the valley of Chamonix, the water-power being obtained from the river l'Arve, near Mont Blanc. The power house contains four Thury 8-pole direct-current generators, which operate at a speed of 240 revolutions per minute, and supply a current of 800 ampères at a potential of 700 volts. These machines were constructed by the Compagnie de l'Industrie Electrique, of Geneva, and each has a capacity of 560 kilowatts. The turbines which are directly coupled to the dynamos have a total capacity of 3,200 horse-power, or 800 horse-power each, and were built by Brenier-Neyret, of Grenoble.

The Usine de St. Michel also supplies power for the manufacture of chlorate of potash, and is located so as to take advantage of the water-power from the river l'Arc. The water conductors are 1.2 meters in diameter, and carry from 5 to 6 cubic meters, the head being about 90 meters. In this power house of St. Michel there are 12 Thury 6-pole continuous-current generators, each driven by a 160 horse-power turbine of the Brenier-Neyret type. These dynamos supply a current of 500 ampères at a potential of 200 volts. There are also four 12-pole Thury direct-current machines, each supplying 1,500 ampères at a pressure of 200 volts. These machines are driven by four 450 horse-power turbines, built by A. & H. Bouvier, of Grenoble.

This same form of Thury 12-pole direct-current machine has also been employed at the Usine de la Praz for the reduction of aluminum. These machines supply 3,000 ampères at 110 volts, and operate at a speed of 250 revolutions per minute. This plant at La Praz utilizes a total of 8,600 horse-power, and is operated by the Société Electro-metallurgique Française. There are two machines at this plant, each of which supply 7,500 ampères at a potential of 35 volts, the speed being 300 revolutions per minute.

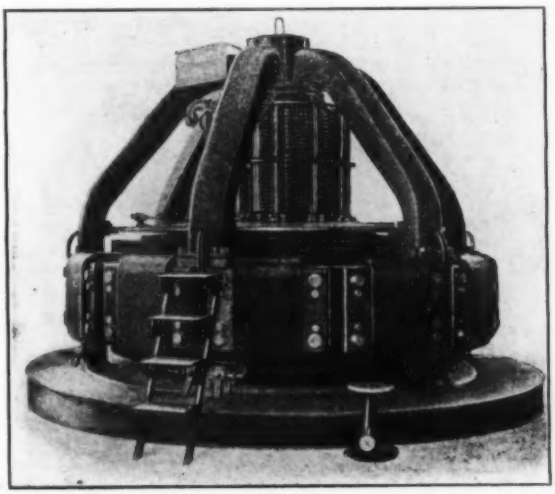
The Usine de Gavet-Clavaux is located in the valley of Bourg-d'Disan, near Grenoble, and supplies current for the production of soda and chlorine. There are two Thury 12-pole



POWER PLANT AT CHEDDES.

generators in this plant, each furnishing a current of 5,000 ampères at 75 volts, or 150 volts pressure. They are driven by four turbines of the Brenier-Neyret type. The products of the electrochemical plant at Monthey, Suisse, are noted for their purity. The sub-station at Monthey is equipped with two motor generators, the motors of which are three-phase machines, operated by a 5,000-volt current, which is transmitted a distance of 8 kilometers from the power station at Bex, Suisse, which is equipped with four 400-kilowatt three-phase machines. These two synchronous motors each have a capacity of 350 horse-power, and drive 6-pole Thury continuous-current machines, which supply 2,000 ampères at 120 volts pressure for the electrolytic work.

The electrolytic generators mentioned above have all been of the horizontal direct-current type, and before taking up the



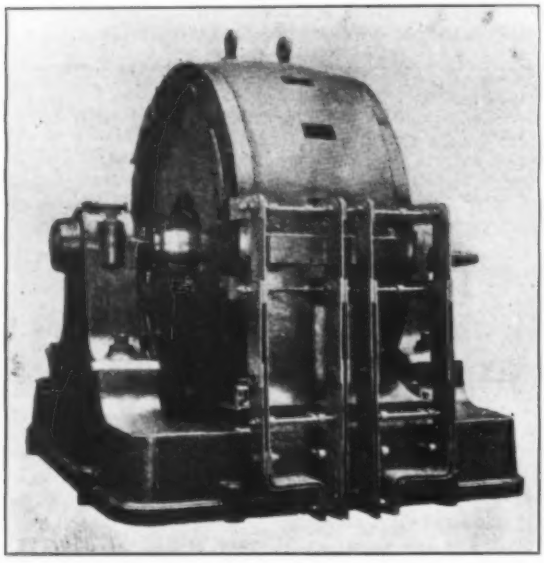
VERTICAL GENERATOR AT CHEVRES-GENEVE.

alternating-current machines for the operation of electric furnaces it may be of interest to consider some of the vertical continuous-current machines used for electrochemical work.

At the Usine de la Volta, at Chèvres-Genève, Suisse, there is in operation a 12-pole Thury vertical generator, which is directly coupled to a 1,200 horse-power turbine, built by Escher,

Wyss & Co. This machine, noted in the accompanying figure, is driven at a speed of 120 revolutions per minute, and supplies a current of 4,000 ampères at a potential of 208 volts. The moving part of this machine weighs 27,500 kilograms, the total weight of the machine being about 60 tons.

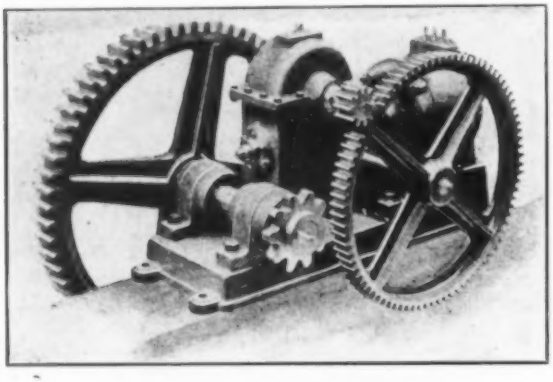
The vertical machine at Harpsborg, built by the Compagnie de l'Industrie Electrique, operates at a speed of 180 revolutions



1,500 HORSE-POWER THURY "CARBURE" ALTERNATOR.

per minute, giving 5,000 ampères at 112 volts. This machine is operated by a 750 horse-power vertical turbine.

The Thury "Carbure" alternator was designed especially for use with electric furnaces for the production of carbide of calcium. The accompanying illustration shows one of these machines of 1,500 horse-power, designed to be operated at a speed of 500 revolutions per minute. It is of the inductor type, there being no windings upon the rotating portion, and the heavy conductors bolted together may be noted in the illustration. This is a single-phase machine, and weighs 32,300



ELECTRICALLY-OPERATED WINDLASS.

pounds. It is 2,720 mm. long, 2,900 mm. high and 2,720 mm. wide. Thury has supplied a 1 horse-power three-phase motor, of 47½ cycles, for an electric windlass to regulate the carbons of the furnaces for the production of calcium carbide. This motor operates at a speed of 1,350 revolutions per minute on a 110-volt circuit, and drives the windlass or carbon regulator by means of the gearing shown in the accompanying illustration. The Société Electrochimique de la Romanche, near Grenoble, have their plant equipped with five of the Thury alternators, each of which has a capacity of 1,200 horse-power and operates at a speed of 350 revolutions per minute.

In Italy the Société Italienne pour la Fabrication du Carbure de Calcium, of Rome, have a very large power plant, using Thury alternators for the production of calcium carbide. The total capacity of this plant is 4,580 horse-power.

Ganz & Co., of Buda-Pesth, installed a number of inductor alternators at the plant at Bozen-Meran, and the current from these machines is used extensively in the works for the production of carbide of calcium. This plant is equipped with six turbines, of 1,200 horse-power each, directly coupled to 1,000-kilowatt three-phase alternators. One of the machines supplies a current of 12,000 volts pressure for long-distance transmission, and two of the alternators supply a three-phase current of 3,600 volts pressure, while the remaining two machines generate currents at both 12,000 volts and 3,600 volts potential. For use in the carbide plant, step-down transformers reduce the potential to that required.

CORRESPONDENCE.

MR. COWLES' PIONEER WORK.

To the Editor of the Electrochemical Industry.

Sir:—I have read the biographical sketch of the life of Alfred H. Cowles in the Electrochemical Industry for October, 1902. I have been and am now counsel for the Electric Smelting and Aluminum Co. in their patent litigation in relation to the manufacture of carborundum. I note in the biographical sketch the reference to the carborundum business is left as though there were doubts as to the carborundum being manufactured in accordance with the process discovered by the Cowles brothers. In justice to Mr. Cowles, I send you a copy of the opinion of the United States Appellate Court, which sat in your city some time over a year ago and passed upon the questions here involved. This decision was the final decision of the highest court. On page 11 of the opinion which I send you, you will note that it was found that the court had "no doubt on the evidence that carborundum can be, and has been, produced under the process covered by any one of the claims of the process patent in suit" (No. 319,795). "So long ago as 1884 the Messrs. Cowles produced it under their process, with and without the use of prepared or preformed central core of resistance material." Samples of carborundum were left by the Messrs. Cowles at the museum of the Institute of Technology in Boston at these early times, and during the course of this case the samples were produced and proven as having been made by the Messrs. Cowles years before Mr. Acheson began to experiment with the Cowles furnaces.

I note the word "said" is used in the same questionable manner in relation to the Cowles' work having opened up the development of calcium carbide. If you care to take the trouble to communicate with Mr. Edward N. Dickinson, Washington Life Building, New York City, the attorney for the Electric Gas Co. and Union Carbide Co., you will be able to learn that these two companies recognized the priority of the Cowles brothers in this field and are licensees under the Cowles patents, though it is a fact that Mr. Edward M. Dickinson was also the attorney for Mr. Thomas S. Willson.

Francis C. McMillin,
Solicitor and of Counsel for
The Electric Smelting and Aluminum Co.
Cleveland, Ohio.

[We would regret exceedingly if the phraseology referred to by Mr. McMillin should convey to the minds of our readers generally any lack of recognition or any sense of depreciation of the splendid pioneer work of Mr. Alfred H. Cowles. The article in question was written at the request of the editor by one who has an intimate knowledge of the career of Mr. Cowles, and the qualifications were introduced merely because the expressions affected were explicit statements of fact beyond the knowledge of the editor, and which, since the article bore

no signature, would, without such qualification, have gone on record as facts within his knowledge. To this confession of a lack of that omniscience which tradition assigns to the editor must be joined a keen regret that the time at our disposal did not permit of an inquiry, the results of which would surely have strengthened, rather than weakened—as Mr. McMillin would believe—a tribute to one who stands so pre-eminent in the field of electrochemistry.—ED.]

BOOK REVIEWS.

LEHRBUCH DER ANORGANISCHEN CHEMIE. By Dr. H. Erdmann, Professor of the Institute of Technology of Berlin. Third Edition. 788 pages, with 291 illustrations, 99 tables and six colored tables. Brunswich: Friedrich Vieweg & Sohn, 1902. Price, 15 marks.

To those who read German, are *conversant* with chemistry and wish a concise presentation of the present condition of descriptive inorganic chemistry, including the most recently discovered facts, this fine volume is heartily recommended. Its appearance is attractive, with its fine paper, clear, black print, well-executed engravings, exhaustive table of contents and well-prepared index. The six colored spectrum plates are beautifully executed, and a pocket contains some loose sheets carrying logarithms, constants for calculations of analyses and commonly-used constants, which are very convenient to have at hand.

The treatment of the various chemical compounds is systematic, well balanced and thorough. The synonyms, in old-style German, French, English and Russian, are given for all important compounds (Latin might have been added). The most recent discoveries in the condensation of gases, rare gases of the atmosphere, electric furnace compounds, radio-active substances and spectrum investigations are referred to more or less fully, and the information brought up to date in a very commendable manner. In some places the work of foreigners, particularly of Americans, is not accorded the relative importance which it deserves, but that is easily pardonable in a text-book intended for German students—one could hardly expect to find it otherwise.

Turning to the other side of the question, the use of the book as a "Lehrbuch der Anorganischen Chemie," we cannot speak of the volume with such high praise. If the aim of a "Lehrbuch" is simply to fill a student full of facts, to make him acquainted with the very latest discovered information, and to feed him upon several half-fledged modern theories, which he is to swallaw whole without asking too many awkward questions, then the book may be styled a success. But if a text-book is intended to teach a student to reflect upon chemical fact; to draw from them by logical inferences their most probable hidden meanings; to reason from cause to effect, and from given conditions to probable results; to understand, in short, the esoteric doctrines revealed only to those who search for truth with enthusiasm and a clear, open mind—then this book is, as such a text-book, a lamentable failure.

We cannot but view in the popularity of such a book as a text-book in the German schools a distinct decadence in the teaching of chemistry. The book is singularly free from the plain presentation of simple chemical facts and the deduction of evident conclusions therefrom. In this respect it is immeasurably inferior to Mendelejeff's splendid "Principles of Chemistry." It is appallingly devoid of statements of facts or principles of chemical energetics. The rich domain of thermochemistry, so pregnant with suggestions and explanations of the *why* and *wherefore* of chemical reactions, is practically omitted. In this respect it is immeasurably inferior to Ditte's excellent "Traité elementaire de la Chimie fondee sur la Thermochimie." The relations of electrical energy to chemical energy, their mutual convertibility and the bearing of this on chemical theory and its importance for the progress of chemistry are so scantily touched on as to be almost undiscoverable. What electrochemistry is given in the book is explained in a manner showing that the writer of this part was ignorant of some of the most elementary principles of electrochemistry. His explanations are often misleading, and unworthy of a mere tyro in the science. These are not random statements, but are provable by numerous quotations which could be made.

Concerning the plain, simple principles of chemistry, the book reflects the modern German practice of making a theory and then twisting or distorting one's intelligence in efforts to prove it true, overlooking or ignoring facts which prove it false. This is all the reverse of the true didactic spirit, which should be the soul of every text-book. When the author states, for example, in his preface, that "the so-long puzzling difference between metals and metalloids now lies clearly before us, and shows that our old masters had a just intuition in laying these two principal divisions at the base of their division of the elements," we are prepared to find the matter cleared up completely in the text. We find the metalloids therein defined, however, as "elements partly gaseous or easily volatile, partly fixed or infusible, conducting electricity and heat poorly, and not so well cold as hot, and lacking metallic luster." If we now suppose that the unhappy student siezes on this halting definition as something a little better than nothing, how are we to imagine his frame of mind when, among 21 elements thereafter named as metalloids, five are described by the author himself as of "perfect metallic luster!" The book abounds in inconsistencies of a similar nature, which may not, it is true, mislead the chemist who uses the book and who can accept such statements at their real value, but where is, meanwhile, our hapless student, who comes to his text-book to be taught.

The great industry and knowledge of the author are proven by the mass of useful information condensed in the book, but the absence of true "teaching quality" in the book, and therefore its distinct inferiority as a *text-book*, are no less plainly in evidence.

JOSEPH W. RICHARDS.

THE OPTICAL ROTATING POWER OF ORGANIC SUBSTANCES AND ITS PRACTICAL APPLICATIONS. By Dr. Hans Landolt, assisted by Dr. O. Schoenrock, Dr. P. Lindner, Dr. F. Schuett, Dr. L. Berndt and Dr. T. Posner. Second edition. Authorized English translation with additions by Dr. John H. Long. 751 pages, with many illustrations. Easton, Pa.: The Chemical Publishing Co. Price, bound in cloth, $7.50.

For those familiar with the second German edition of this work, brought out in 1898, very little need be said, except that the translator has done eminent credit to his work. In general it may be noted, however, that the subject-matter is very happily arranged, and the eye of the reader will readily catch the method of classification that is followed.

The text is introduced without needless historical retrospect, or, in fact, any at all; and the symbols, formulæ and equations that are used throughout the book are explained in the first pages instead.

It may be stated that a book devoted so much to theoretical considerations, as this is, should contain as much matter of a practical nature as is given here. For, besides the considerable amount of space devoted to polariscopes and saccharimeters, very complete methods of optical sugar analysis, determinations of camphor, nicotine, cinchona alkaloids, cocaine, etc., are described in detail. The methods for the determination of the sugars are given concisely, yet as complete working methods; and although they are the official methods of the German Government, they are nearly universally adaptable and, we may say, acceptable. For additional methods, the reader is referred to United States Treasury Department bulletins and to other American and English sources.

The only thing that might be said adversely in criticism is

that it would seem appropriate for a book of this kind to be better and more substantially bound. But such a consideration is small compared with the value of the material that is between the covers.

The work is divided into the following parts: I: General Conditions of Optical Activity. II: Physical Laws of Circular Polarization. III: Numerical Values for the Rotating Power. —Specific Rotation. IV: Apparatus and Methods for the Determination of Specific Rotation. V: Practical Applications of Optical Rotation. VI: Constants of Rotation of Active Bodies. From this it will be seen that the book will appeal very generally to the large body of scientific workers.

BOOKS RECEIVED.

A Text-book of Inorganic Chemistry. By Dr. A. F. Holleman. Rendered into English by Herman C. Cooper, Ph.D., with the co-operation of the author. New York: John Wiley & Sons. 458 pages, with 84 illustrations. Price, $2.50.

Elementary Chemistry. By F. W. Clarke and L. M. Dennis. New York: American Book Co. 340 pages, illustrated. Price, $1.10.

Vorlesungen ueber Theoretische und Physikalische Chemie. By J. H. van't Hoff. Braunschweig: Friedrich Vieweg & Sohn. Vol. I: Die Chemische Dynamik. 251 pages, illustrated. Price, marks, 6. Vol. II: Die Chemische Statik. 148 pages, illustrated. Price, marks 4. Vol. III: Beziehungen zwischen Eigenschaften und Zusammensetzung. 136 pages, illustrated. Price, marks 4.

Acht Vortraege ueber Physikalische Chemie, gehalten auf Einladung der Universität Chicago, 20 bis 24 Juni, 1901. By J. H. van't Hoff. Braunschweig: Friedrich Vieweg & Sohn. 81 pages, illustrated. Price, marks 2.50.

ELECTRIC LABORATORY FURNACES.

In the following we give a description of some new forms of electrochemical furnaces which are now being put on the market by Eimer & Amend, New York City, and which are specially designed for chemical work in the qualitative, quantitative and metallurgical laboratories. It is thought that these forms of furnaces will be found extremely useful and convenient for laboratory work, as they give the highest temperatures required, are perfectly controllable and absolutely clean.

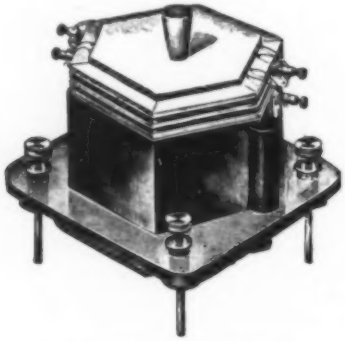


FIG. 1—HEXAGONAL FURNACE.

There is no reduction or oxidation by gases.

The special advantages claimed for these new types of electric furnaces over other electric furnaces are that they are strong and compact, and are built in sections, so that all parts can readily be replaced in case of accident. They are operated at the ordinary electric light pressure of 110 volts, and are not liable to get out of order. The further advantages of these furnaces are that the inside surface is made of smooth material, which does not crumble or crack, and the substance treated can readily be observed. The platinum ware used in these furnaces will last twice as long as in the old-fashioned blast lamp methods. The temperature in these furnaces ranges up to 1,500° C. (2,700° F.); in fact, to the melting point of platinum.

The following are the standard types and sizes: A furnace of square cross section is built in two sizes; the smaller size takes the regular-shape platinum crucibles of 10, 15 and 20 cc. capacity, the available inside space being 1 to 1½ inches by 1 to 1½ inches, the current required being 10 ampères and the voltage 110. The larger size, for 30, 40, 50 and 60 cc. platinum crucibles and Eimer & Amend's new carbon determination apparatus, has an inside space of 2 x 2 inches, the current required being 12 ampères and the voltage 110.

Fig. 1 shows an extra large hexagonal furnace, as used by Professor Landolt and Professor Traube, in Berlin, and others for atomic weight determinations, etc. It has room for

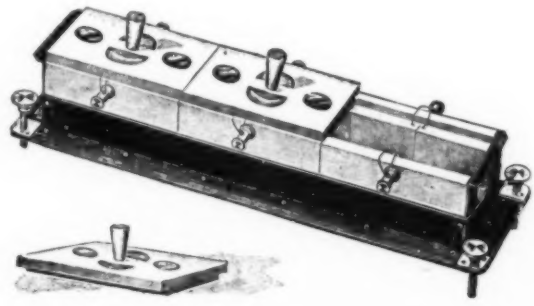


FIG. 2—SECTIONAL COMBUSTION FURNACE.

two platinum vessels for check work, etc., the current required being 15 ampères and the voltage 110.

A muffle-shaped furnace, with front shelf, is made in two sizes. The large size has an inside space width of 3⅛ inches; depth, 3⅛ inches; height, 1½ inches. It takes all regular platinum, incinerating milk and other flat platinum dishes, as well as medium-sized wasting dishes, scorifiers, cupels, etc., the current required being 12 ampères at 110 volts. The smaller size has an inside space of 1¾ inches in depth, 1 inch in width and 11 to 16 inches in height. It is used for determining the fusing point of metals, minerals, enamels and for other small thermic work, the current required being 7 ampères at 110 volts.

Fig. 2 shows a sectional combustion furnace for tubes up to 1 inch diameter, the heating surface being 15 inches in length. The current required is 10 to 15 ampères at 110 volts. This furnace permits of progressive heating from rear to front end, and *vice versa*.

Eimer & Amend also sell an electric furnace of the Moissan type in improved form. The size of the inside space is 6 x 5½ x 5½ inches. It is perfectly adjustable and accessible for experimental arc work, and requires a current of 100 ampères at 50 to 60 volts.

For measuring the whole range of temperature in these furnaces, the improved Le Chatelier's pyrometer, with electric couples with double wires of platinum rhodium, is very suitable. The pyrometers, as placed on the market by Eimer & Amend, are correct indicators of temperature from the normal up to 1,600° C. (3,000° F.), and are tested by the German Reichsanstalt. They are provided with a double scale, a direct reading temperature scale in degrees centigrade up to 1,600, as well as a millivolt scale.

Messrs. Eimer & Amend have also placed on the market an electric heating apparatus for distilling ether from glass vessels without danger. It is provided with a regular Edison incandescent lamp for 110 volts, and is furnished in two sizes, the one for pint flasks and the other for quart flasks.

VOLTMETER FOR ELECTROPLATING PLANTS.

Great progress has been made in recent years in the methods of electroplating. By careful observation, the practical electroplater has studied the chemical composition of those solutions which are best adapted for obtaining a certain metallic deposit, and at the same time he has learned by experience what are the best electrical conditions—especially the best current density—for obtaining a satisfactory deposit of uniform thickness in the shortest space of time. After he has found once the best electrical conditions, it is only necessary that he should be enabled to reproduce them easily and safely at all times. For this purpose it is of the greatest importance that either the electromotive force between anode and cathode, or the current flowing through the bath, be accurately measured. The ordinary galvanometer is insufficient, and often misleading. Experience has shown that only the very best voltmeters or ammeters should be used in electroplating plants. They should be so constructed as to indicate quickly and accurately any sudden changes in current, and should be direct reading in volts or ampères; and their indications should not be subjected to gradual changes. A sensitive voltmeter will indicate the slipping of belts, short-circuiting in tanks and any irregularity in the power supply.

The adjoining diagram shows the Starrett improved voltmeter, made by the Hanson & Van Winkle Co., Newark, N. J., for the special use of electroplaters. These voltmeters have a

VOLTMETER FOR ELECTROPLATING PLANTS.

scale from 0 to 6 volts and upwards. The scale is divided into 120 divisions, so that each division represents 0.05 volt, and, when in connection with the switch board, the voltmeter enables the plater to study carefully all the requirements which insure good results.

These voltmeters are of the permanent magnet type, and by the process of treating the magnets the manufacturers have succeeded in insuring the permanence of the magnets for years without any appreciable change, unless placed within a powerful magnetic field. For this reason they should not be placed close to a dynamo, nor should a current be passed through them in a reverse direction, as this has a tendency to demagnetize the magnet.

These instruments, as made by the Hanson & Van Winkle Co., are furnished with binding posts for fifteen tanks, thus enabling the operator to use one instrument for any number of tanks up to fifteen by means of a shunt, from which the wires run to each tank. The operator simply moves a switch, and by this arrangement, and in connection with the switch board, he can easily control the voltage for each tank and the current passing through it. It is evident that this arrangement greatly simplifies the methods for exactly reproducing the electrical conditions required for obtaining satisfactory results.

PERSONAL.

MR. D. R. LOVEJOY, of the Atmospheric Products Co., Niagara Falls, N. Y., has recently sailed for Europe.

DR. R. OGDEN DOREMUS, New York City, recently resigned from the presidency of the Greater American Mining Co., New York.

MR. WILLIAM C. NICHOLS, president of the Nichols Chemical Co., copper refiners, of New York, recently visited the Granby Consolidated Mining, Smelting and Power Co's mines and smelter in the Boundary District of British Columbia.

COL. ALLAN C. BAKEWELL, recently elected president of the Sprague Electric Co., was for the past three years the second vice-president and general manager of this company. In his place, Mr. M. D. Clarence Durland has been elected second vice-president, who, for the last three years, has been assistant general manager of the company.

DR. A. E. KENNELLY has recently returned to Philadelphia from a cable-laying trip in Mexican waters, and has taken up his duties as professor of electrical engineering in Harvard University.

DR. JOHN F. KELLY, of the Stanley Electric Co., has just returned from a long trip abroad.

American Electrochemical Society. — The following-named gentlemen have been elected members at the directors' meeting, held November 6th: Erik W. Tillberg, Worcester, Mass.; Geo. W. Patterson, Jr., University of Michigan, Ann Arbor, Mich.; A. A. Knudson, New York; Arthur E. Kennelly, Harvard University, Cambridge, Mass.; C. S. Bradley, New York; Walter T. Taggart, Philadelphia, Pa.; Barthold E. Schlessager, Boston, Mass.; Max Mauran, Niagara Falls, N. Y.; W. E. Goldsborough, Lafayette, Ind.; C. C. Speiden, Summit, N. J.; F. B. Crocker, New York; Charles J. Greenstreet, Fort City, Pa.; Ashmead G. Rodgers, Niagara Falls, N. Y.; F. J. A. McKittrick, Schenectady, N. Y.; Wm. O. Mathews, Dover Bay, Ohio; E. A. Deeds, Niagara Falls, N. Y.; A. T. Lincoln, Urbana, Ill.; J. G. Zimmerman, Madison, Wis.; James L. Ervin, Washington, D. C.; Geo. O. Knapp, Chicago, Ill.; C. E. Freeman, Chicago, Ill.; Charles F. Vaughn, Niagara Falls, N. Y.; Harold Childs Pease, Schenectady, N. Y., and Fritz Haber, Karlsruhe, Germany.

INDUSTRIAL NOTES.

WE have received from Messrs. Baker & Co., Newark, N. J., the tenth edition of their handsomely-illustrated pamphlet, "Data Concerning Platinum." It gives illustrated descriptions of the various types and forms of platinum crucibles, dishes, pans, muffles, spatulas, triangles, filter cones, combustion boats, spoons, electrodes, tweezers, tongs, retorts, baskets, pots, platinum tips for lightning rods, platinum gauze, etc. Some valuable information is given on the use and care and on the cleaning of platinum ware. Special notes refer to platinum stills for the concentration of sulphuric acid and to platinum protective fuses for telegraphic and telephonic work. Several tables at the end of the book will be greatly appreciated by the practical man. They give the weight per foot of platinum wire in troy weights and grams; also the weights per square inch of platinum sheet or foil. Other tables give the number of square inches of platinum sheet and foil per troy ounce, the weight per foot of platinum wire in troy ounces and the number of feet of platinum wire per troy ounce. There are also comparative tables of lengths, areas and volumes; tables of specific gravities and melting points; a comparative table of wire gauzes, sulphuric acid tables, etc.

THE C. W. Hunt Co., West New Brighton, N. Y., inform us that at the Dusseldorf Exhibition, which has just terminated, the highest award of merit, the gold medal, was awarded to their Hunt conveyor.

DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.

This digest of electrochemical United States patents prior to July, 1902, will be one by classes, setting out for comparison in each class those devices which have the same object, or those methods which seek the same results. In each class the patents will be arranged chronologically. The digest will be complete in the sense of covering every point which is touched upon in the original specification.

DIAPHRAGM CELLS FOR THE PRODUCTION OF CAUSTIC ALKALI.*

415,644. November 19, 1889; Georg Kerner, of Frankfort, and Julius Marx, Ulm, Germany.

Electrolyzes sodium chloride or "mixed salts of the alkalies or alkaline and other earths, it being known that the current decomposes these salts in a definite order, so that the several bases and acids can be obtained separately." The electrolyte may be heated or cooled. The anode and cathode products are kept apart by a diaphragm, and removed by precipitation or otherwise. When electrolyzing sodium chloride, the dissolved chlorine is removed "by exhausting or drawing, or by forcing air through the apparatus." Says that sodium chlorate gradually accumulates in the solution and is decomposed by the addition of potassium chloride, giving potassium chlorate. When sulphates are electrolyzed, removes the sulphuric acid from the anode compartment by the addition of calcium carbonate, phosphate or chloride. Converts the caustic soda produced in the cathode compartment into a bicarbonate by the injection of carbon dioxide; or may add magnesium carbonate or carnallite to produce a double carbonate, or may produce a double carbonate of sodium and zinc. Afterward decomposes the sodium bicarbonate with caustic soda. Decomposes the double carbonates by boiling or passing steam through them. May effect the precipitations in the electrolytic cell or in separate vessels, returning the residual liquors after enriching them with salt. Causes the anode and cathode solutions to flow in opposite directions, to diminish loss by re-combination.

442,334. December 9, 1890; Isaiah L. Roberts, Brooklyn, N. Y.

Anode, a compressed mixture of retort carbon and ozokerite. Surrounds anode by a mass of finely-divided anthracite coal, held in a bag of cotton, strengthened by asbestos or wire gauze. Gaseous anode products and any overflow escape through a layer of granular carbon and a lateral pipe at the top of the bag, the neck of which is sealed by asphalt or tar. Iron vessel serves as cathode.

442,396. December 9, 1890; Isaiah L. Roberts, Brooklyn, N. Y.

Electrolytic vessel, consisting of an inner and outer wooden box, with an intermediate space filled with tar or asphalt. Walls of anode compartment of glass or slate. Diaphragm of asbestos cloth, between asbestos boards, and inclosed in cotton cloth, the whole treated with sulphuric or hydrochloric acid. Anodes of carbon, or an alloy of lead, antimony and mercury. Cathode, copper.

442,494. December 9, 1890; Isaiah L. Roberts, Brooklyn, N. Y.

Apparatus similar to 442,334, except that a glass cylinder extends from the neck of the bag down into the packing of coal dust.

450,103. April 7, 1891; Ernest Arthur Le Sueur, Ottawa, Canada.

Vessel, a shallow open tank, containing a number of anode bells of stoneware. Each bell is closed at its lower end by a diaphragm of vegetable parchment, beneath and in contact with which is the cathode, consisting of a number of sheets of wire gauze riveted together. One rivet of each cathode extends down into a mercury cup in the bottom of the tank. Cathode connections lead to each mercury cup. A single cathode may underlie all the bells. The tank may be of iron, and also act as cathode. Each bell is supported in the tank in a slightly inclined position, to facilitate escape of hydrogen from the cathode. Each bell is nearly filled by an anode consisting of a large number of carbon rods, secured at their upper ends in a lead plate and extending down nearly to the diaphragm. Through each bell pass supply tubes, which dip into the electrolyte, and an outlet for chlorine.

450,104. April 7, 1891; Ernest Arthur Le Sueur, Ottawa, Canada.

Inclined anode bell of earthenware, supported on the bottom of an open tank. Lead tubes pass through the top of the bell, and serve both as supports for the anode and conduits for introducing brine and removing chlorine. Lower end of bell closed by a diaphragm and wire gauze cathode. Diaphragm clamped to lower edge of bell by a metal ring, within which sufficient hydrogen accumulates to press diaphragm against lower edge of bell, preventing leakage. Electrolyte in bell maintained at a somewhat higher level than outside. Automatic device cuts off electric current in case the diaphragm ruptures.

468,880. February 16, 1892; Ernest Arthur Le Sueur, Ottawa, Canada.

Anode bell has an outer overflow passage to indicate level of liquid within. Anode supported in bell by a central stem, having a passage for introducing brine. Upper end of stem surrounded and supported by an inverted cup, having sealed chlorine outlet. Cup supported on bell by adjusting screws or wedges.

480,491. August 9, 1892; Elisha B. Cutten, New York, N. Y.

Vessel of iron serving as cathode. A horizontal glass plate near bottom of vessel supports a glass trough, within which is a carbon bar imbedded in insulation. Vertical anode rods, arranged in a row, are screwed into the carbon bar at their lower ends. End of carbon bar extends out through vessel and carries anode terminal. A transparent glass bell incloses upper ends of carbon rods. An annular sheet-metal hood fills the space between sides of the vessel and bell, its flanges dipping into the electrolyte. A pipe for removing hydrogen leads from this hood to a suction pump. A pipe for removing chlorine leads from glass bell to a suction pump. A body of solid salt is maintained within the vessel, resting on the glass plate near the bottom and extending up to the upper ends of the anode rods. An inclined gutter at the bottom of the vessel serves to remove caustic. A passage for the introduction of strong brine extends through the carbon anode bar, and branch ducts open up between each pair of anode rods. Inside of iron vessel coated with varnish to a point below lower edge of glass bell. May electrolyze calcium or magnesium chloride.

481,407. August 23, 1892; Farnham Maxwell Lyte, London, England.

Production of caustic alkalies and chlorine. First, produces sodium ferrate, nitric oxide and oxygen by heating a mixture of sodium nitrate and ferric oxide; second, boils the ferrate with water, producing caustic free from iron and ferric hydrate; third, decomposes the ferric hydrate by heat, producing ferric oxide, which is returned; fourth, produces nitric acid by adding air and water to the nitric oxide and oxygen from the first reaction; fifth, combines the nitric acid with litharge to produce lead nitrate; sixth, decomposes the lead nitrate with sodium chloride, producing lead chloride, which is melted and electrolyzed, and sodium nitrate, which is returned. Converts the electrolytic lead into litharge, which is returned.

(*To be continued.*)

* For a critical analysis of the problem the reader is referred to the article of C. P. Townsend on page 23 of the September issue of this journal.